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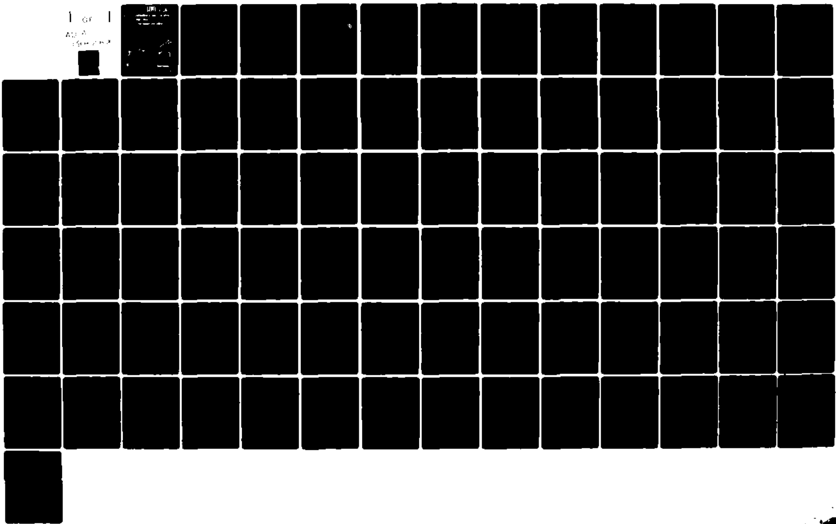

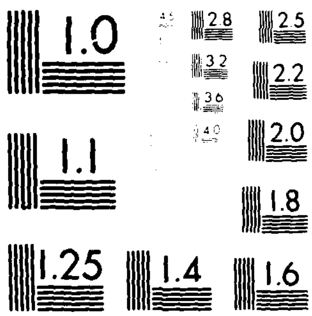

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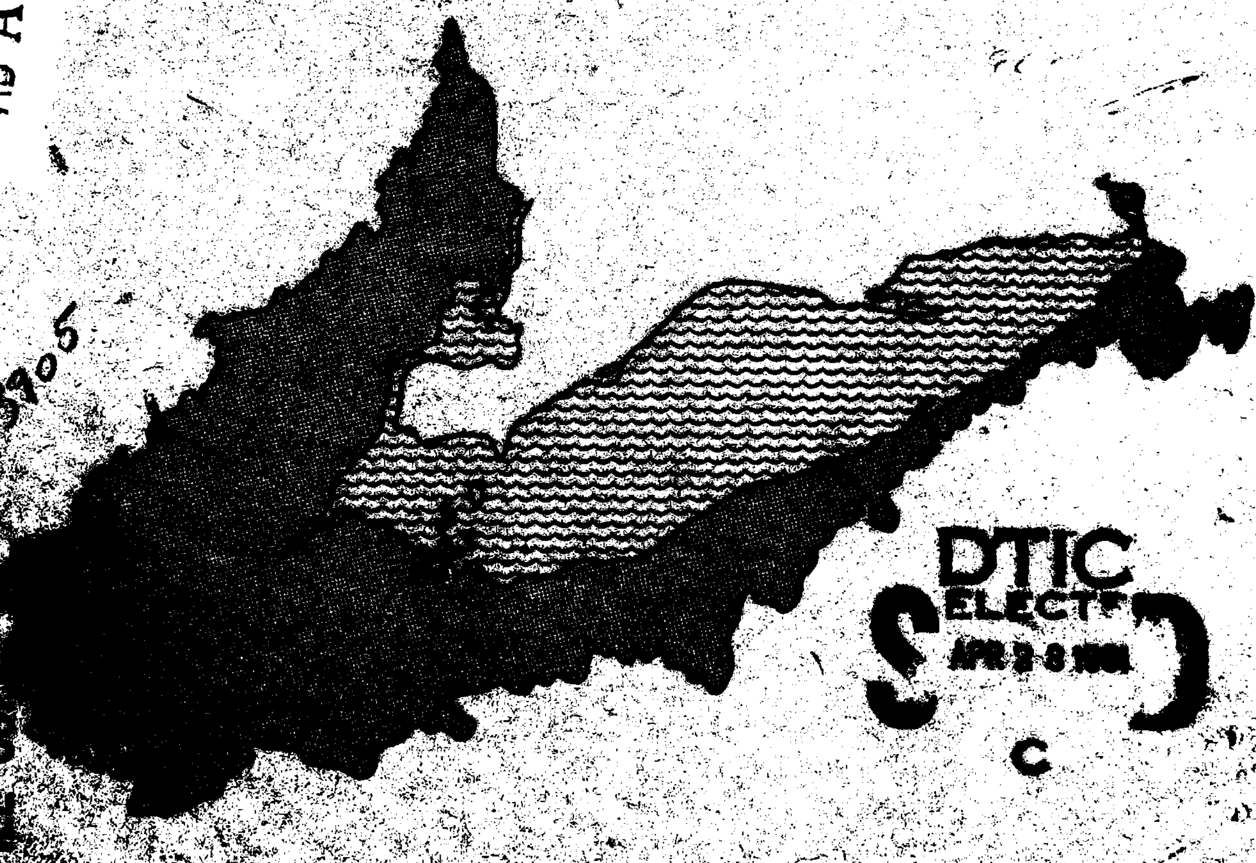
ENVIRONMENTAL QUALITY OF UPPER HONEY CREEK: A PRELIMINARY ASSESSMENT



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The biological, physical, and chemical components were measured a total of four times in 1979 and 1980 at six sampling stations within the watershed. Substrate types and distributions were measured on two occasions at each station.

This preliminary study indicated (1) large spatial and temporal variability of stream substrates and biological communities, (2) in general, "good" stream quality at all stations, as reflected by the biological components, (3) fecal contamination at all stations, (4) an observable effect of septic tank effluents on the nutrient and bacteriological quality of the stream draining Tiro. Recommendations are made for further investigation of the effects of changing agricultural BMP's on the in-stream quality of the Honey Creek watershed.

Environmental Quality of Upper Honey Creek: a Preliminary Assessment

by

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ABSTRACT

In 1978 the upper Honey Creek watershed of the Sandusky River Basin in Ohio became part of a national demonstration area for agricultural best management practices (BMP's), especially no-tillage. The present study was conducted in conjunction with studies of stream flow and sediment and nutrient loadings in the Honey Creek drainage. Baseline information was gathered on physical, chemical, and biological parameters which might later reflect the effects of large-scale implementation of no-tillage and other BMP's.

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INTRODUCTION

In agricultural watersheds, farming practices have a large impact on overall stream water quality from the standpoint of sediment, nutrient, and pesticide loadings to the streams (U. S. Army Corps of Engineers, 1979; International Joint Commission, 1980). Therefore, changes in agricultural management practices have a direct influence on stream water quality. In the Sandusky Basin (Figure 1), especially in the tributary watershed of Honey Creek, conservation tillage measures, including no-tillage and minimum tillage, are being implemented on a large scale. In 1978, as part of the U. S. Army Corps of Engineers' Lake Erie Wastewater Management Study (LEWMS), the Honey Creek Watershed became the site of a national demonstration project for no-tillage agriculture. The watershed was also selected as a national special project area for the Rural Conservation Program (RCP) supported by the Agricultural Stabilization and Conservation Service (ASCS). The Soil Conservation Service, three county Soil and Water Conservation Districts, and the county ASCS committees are cooperating in these programs. Independently and through these demonstration projects, conservation tillage, especially no-tillage, is being adopted by an increasing proportion of the farmers in the watershed each year.

The concept of no-tillage agriculture has been reviewed recently (Giere et al. 1980, Phillips et al. 1980, Triplett and Van Doren 1977). The major advantages of no-tillage are (1) reduced soil erosion caused by wind and water, (2) increased

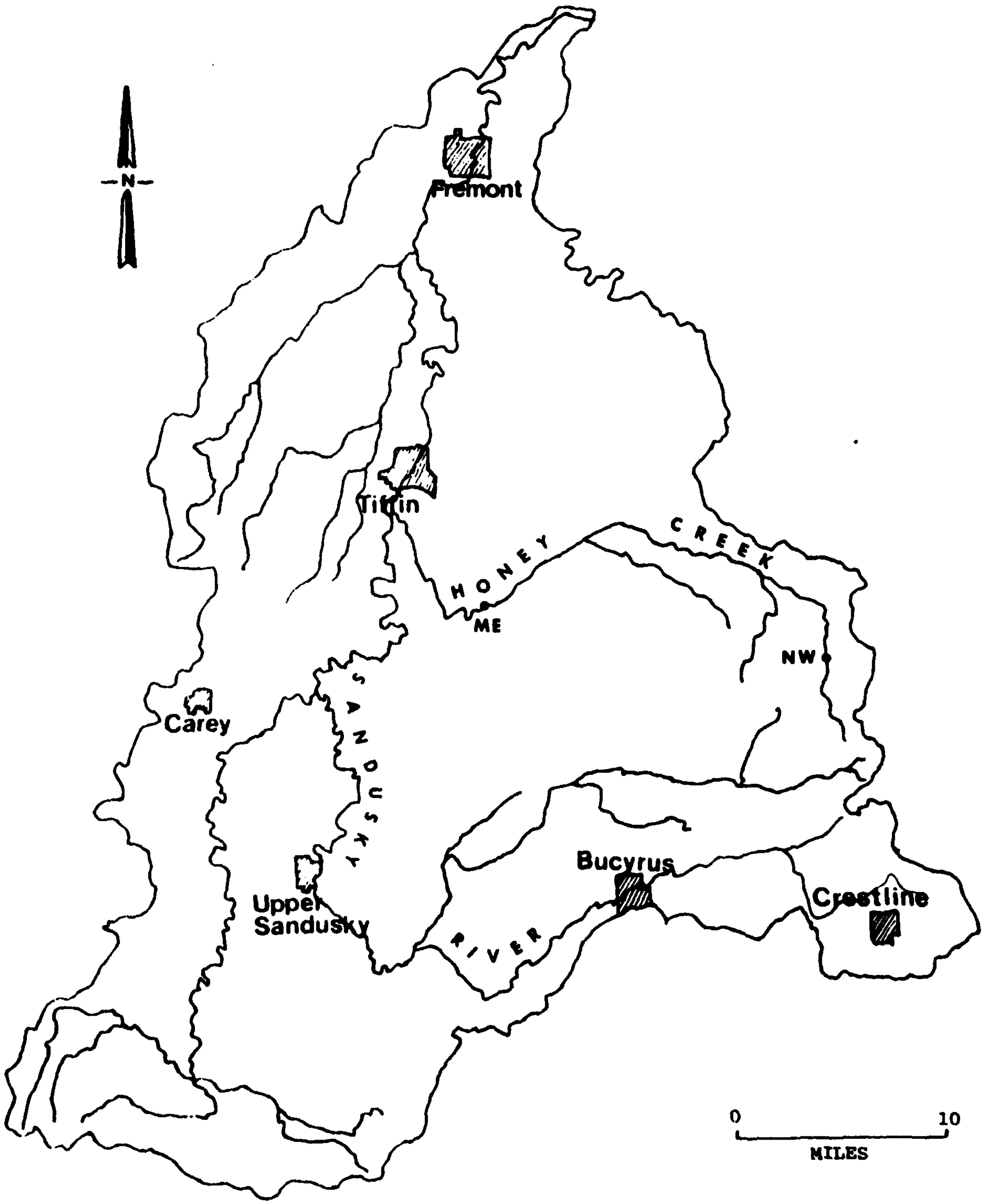

Figure 1. The Sandusky River Basin, Ohio, showing the locations of the Melmore (ME) and New Washington (NW) gaging stations on Honey Creek.

acreage available for row crops because of the capability of growing these crops on sloping land which is too erodable under conventional tillage, (3) reduced energy requirements, (4) improved timing of planting and harvesting because no-tillage allows these activities under a wider range of soil moisture conditions, (5) decreased soil water evaporation and increased infiltration of water into the soil, and (6) smaller investment in machinery.

Disadvantages of no-tillage include (1) increased populations of insects, rodents, and disease-producing organisms because of a more favorable habitat provided by no-tillage, (2) a greater management ability required for successful yields, (3) considerably reduced soil temperatures during spring because of mulch overlying the soil surface, causing delayed planting or slower plant growth, (4) usually an increase in the application of herbicides and insecticides, and (5) increased leaching of nitrate from poorly drained soils as well as increased denitrification (Phillips et al. 1980).

The large-scale conversion to no-tillage agriculture in the Honey Creek watershed may include all of the above benefits and disadvantages. Many of these may be expected to have an effect on the water quality of the first, second, and third order streams of the watershed, as well as on the Sandusky River and ultimately Lake Erie. Reduced erosion would be accompanied by a reduced sediment load. Concentrations of pesticides in stream water may either decrease or increase, depending on the pesticides being applied and the relative

contribution of tile drainage systems to the export of residual pesticides. Phillips et al. (1980) reviewed limited documentation which indicates that atrazine and simazine, two widely used herbicides in the Honey Creek watershed which do not bind tightly to soil particles, were present in no greater concentrations in surface runoff from no-tilled fields than from conventionally tilled fields, and that some pesticides are degraded more rapidly in the soil under no-tillage conditions. However, where no-tillage is being applied on soils underlain by extensive tile drainage systems, as in the Honey Creek Watershed, the export of water soluble herbicides such as atrazine may be measurably greater than the export from conventionally tilled fields. Under present management, atrazine levels observed in the Sandusky Basin have been much higher than levels previously reported in the midwestern U.S. and southern Canada (Setzler 1980, Morley 1977, Muir and Baker 1976, Richard et al. 1975). The herbicide paraquat, which is often used in conjunction with no-tillage, binds tightly to soil particles (Pope and Benner 1974). Although no-tillage greatly reduces soil erosion, some sediment-bound paraquat might be expected to enter stream systems draining no-tillage fields during spring storm events.

The development of a surface mulch layer and the accompanying increase in the infiltration of rainfall and snowmelt into the soil may enhance stream quality by causing a more uniform stream discharge with reduced storm hydrograph peaks. In turn, greater stability of stream substrates may

result.

Accompanying reduced erosion, stream phosphorus loadings would be expected to decrease (U. S. Army Corps of Engineers, 1979; International Joint Commission, 1980). However, stream nitrate concentrations may increase, as the result of increased leaching (Phillips et al. 1980). Compounding the question of stream nutrient loadings are additional sources consisting of septic tanks and livestock feedlots, both of which are distributed throughout the Honey Creek watershed.

As an integrated effect of all of the physical and chemical changes in the Honey Creek watershed accompanying no-tillage agriculture, the structure and productivity of the biological stream community may change. For example, a reduction in phosphorus loadings would most likely cause a change in community structure and productivity; an increase in stream bottom stability would increase the potential for colonization and persistence of benthic organisms, which would probably result in greater densities of organisms accompanied by greater overall productivity.

In order to be able later to identify those changes in stream quality which might accompany large-scale conversion to conservation tillage systems in the Honey Creek watershed, it is important to obtain an understanding of the water quality of the watershed under present agricultural management, which is primarily conventional tillage. Therefore, the purpose of this study was to gather baseline information for a number of physical, chemical, and biological parameters which might later

reflect the effects of large-scale no-tillage implementation. An important aspect of this pilot program was to assess the usefulness of each of the parameters selected for measuring future water quality changes, and to identify those parameters which could probably be most successfully applied toward detecting the extent of those changes. The parameters included (1) stream community structure, (2) substrate types and distributions, (3) physical and chemical water quality, and (4) nutrient exports from the town of Tiro.

STUDY AREA

The study area was limited to the upper Honey Creek drainage (Figure 2), which is a focal area of the Honey Creek demonstration projects and hence an area likely in the future to be converted more extensively to no-tillage agriculture. Six sampling stations, each comprising 100 m of "typical" stream reach, were selected in the upper Honey Creek watershed to represent the mainstream and its tributaries (Figure 2). All stream reaches flowed continuously throughout the year of study, and therefore may be considered to be first-order streams except for station 1, which was third-order. The streambed within each stream reach consisted primarily of sand and silt, although stations 3 and especially 4 had some stones and boulders, and each reach except station 5 contained areas of pools and riffles. Stations 1, 2, 4, and 6 were bordered by trees which provided a partial canopy over the stream; stations 3 and 5 had only a few trees along their banks, which were primarily grassed. Stations 1 through 4 were located in the eastern, morainal portion of the upper Honey Creek watershed, while stations 5 and 6 drained the western, lake-bed portion of the drainage. Stations 3 and 4 were selected to determine in a preliminary manner whether Tiro exerts a detectable influence on the water quality of the first-order stream flowing past it.

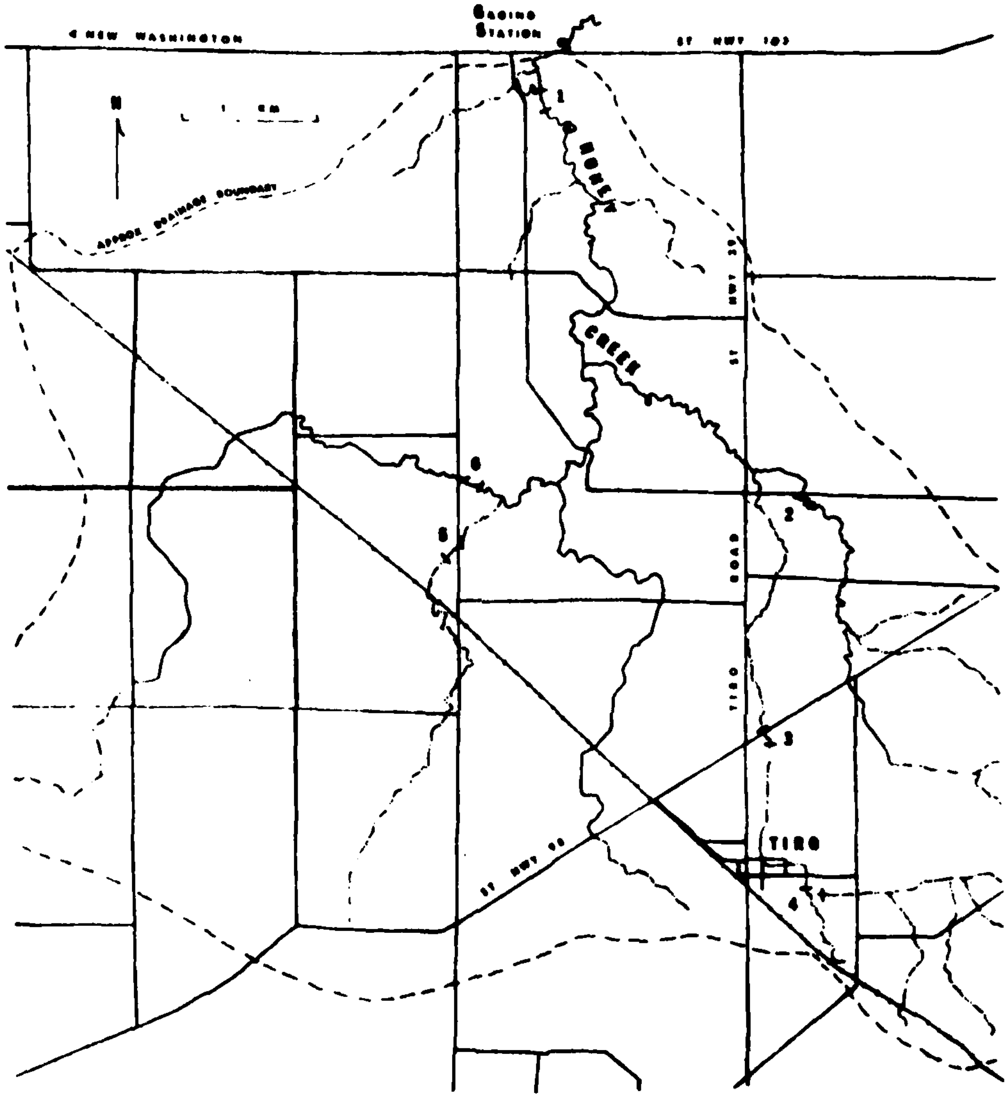

Figure 2. The upper Honey Creek watershed (modified from U.S.G.S. 7.5 minute series maps, New Washington and Shelby, Ohio, quadrangles). The six stream sampling stations are numbered with bars delimiting the approximately 100 m reaches. The New Washington gaging station is located at the arbitrary downstream boundary of the watershed.

MATERIALS AND METHODS

Biological Stream Community Investigations

Periphytic Algae. Qualitative and quantitative collections of periphytic algae were made from natural substrates on four dates from 1 August 1979 through 23 June 1980. Qualitative samples were collected from a variety of natural substrates and composited, while quantitative samples were stripped from bottom substrates by means of 50 mm diameter plastic petri dishes with tight fitting lids. All samples were transferred into sterile poly bags and immediately preserved with a modified Lugol's iodine solution (Meyer 1971).

Fine particulate matter(primarily fine clays), which often interferes with the identification of the specimens, were decanted from the samples following sedimentation. Sample volumes were adjusted to provide suitable algal densities for enumeration and split into two fractions. One fraction was processed according to Van def Vreff (1937) for the confirmation of the Bacillariophyceae (diatoms). Aliquots of the remaining fraction were sedimented and temporary mounts were prepared for the analysis of all algal groups.

Taxonomic identification and enumeration of periphyton samples were performed using the inverted microscope technique (Utermohl 1958, Lund 1958) using a transect approach. Specimens containing a protoplast were identified to the lowest possible taxonomic level (usually species) with the aid of the following references: Butcher 1971; Cleve-Euler 1951, 1952,

1953, 1955; Huber-Pestalozzi 1942; Huestedt 1939; Lowe 1975; Patrick and Reimer 1969, 1975; Prescott 1973; Tiffany and Britton 1951; and Whitford and Schumaker 1973.

Individual algal cells were the reporting unit used in the periphyton enumerations. Colonial or filamentous algae were recorded as individuals equivalent to the total number of cells within that algal form. Densities were expressed as cells per square millimeter. Densities were calculated based on the area examined containing a minimum of 500 specimens or a maximum of 20 ten mm strips. Periphyton densities were derived from the following:

$$\text{Density (cells/square mm)} = \frac{A * B}{C * (D/E) * F}$$

where A = Number of reporting units observed

B = Total area of the counting chamber base (square mm)

C = Area of counting chamber base examined (square mm)

D = Volume of sample aliquot (ml)

E = Adjusted sample volume (ml)

F = Area of substrate sampled (square mm)

Macrophytes. Macrophytes were defined as "aquatic plants possessing a multicellular structure with cells differentiated into specialized tissues" (Weber 1973). Each of the six

sampling stations was observed during each sampling event for the presence and location of macrophytes. Representative specimens were collected, and Muenscher (1959) was consulted for identification.

Macroinvertebrates. A qualitative sample of the macroinvertebrates was obtained at each station each sampling period. Qualitative methods included use of a "kickscreen" in reaches with a moderate to swift current and use of dipnets in areas of debris, slow currents, or undercut banks. An attempt was made to expend equal effort at all the stations. Organisms from all microhabitats were combined into a single sample per station and were preserved in a solution of 85 percent ethanol, 5 percent glycerin, 10 percent water (AGW).

At each station each sampling period, two quantitative samples were obtained, one from each of the two predominant sedimentary substrates, where at least two sedimentary substrate types were present. A Petersen dredge (area 0.0623 sq. m) was employed for the first sampling period, and a Ponar dredge (area 0.0529 sq. m) was used thereafter. The quantitative samples were sieved in the stream through a No. 30 mesh screen, and the residues were returned to the laboratory in AGW. In the laboratory, these samples were stained with Phloxine B and the invertebrates were hand-picked from the sediments and debris.

The organisms were identified to the lowest taxon practical. Because of the very large numbers of oligochaetes and midgefly larvae obtained, these two groups were not

identified at lower taxonomic levels. For some samples, a subsample of the oligochaetes was counted, and the number obtained was extrapolated to the total sample. Sources consulted for identification of specimens included Harman and Berg (1971), Hilsenhoff (1975), Hobbs (1976), Holsinger (1976), Merritt and Cummins (1978), Pennak (1978), and Williams (1976). Analyses of variance were computed using the statistical package MINITAB (Ryan et al. 1980).

Fishes. Upper Honey Creek was sampled for fishes on 31 August and 8 November 1979, and 2 April and 2 May 1980. As much as possible of the stream reach comprising each station was sampled with a 4 ft by 12 ft minnow seine with a one-eighth inch mesh. Representative specimens of each species were preserved in the field in 10 percent formalin. On the first two sampling dates, the specimens were placed on ice and later frozen pending identification and possible future pesticide analysis. Because this resulted in physical deterioration of the specimens and consequent difficulty in identification, these specimens were also placed in formalin. Prior to identification, the specimens were transferred to AGW. Trautman (1957) was the primary source for identification.

Substrates

During the fall sampling period, sketch maps were prepared, indicating the general distribution of substrate patches of obviously different grain size, such as sand and gravel bars, silt beds, and non-depositional areas, usually

glacial till.

At each station, four quantitative samples were taken by forcing a plastic sample jar into the substrate to a depth of about 9 cm. The spot where each sample was taken was marked on the sketch map to permit sampling nearly the same spot in the spring.

During the late spring (May) sampling period, the fall sketch maps were compared with the localities to determine if there had been major shifts in the distribution of the substrate patches. Samples were taken as close to the location of the fall samples as possible. This sampling scheme produced 24 pairs of samples for grain size analysis.

Samples were dried in shallow containers at air temperature, disaggregated if necessary by gentle pressure from a rubber stopper, and weighed on a triple beam balance to determine total weight to the nearest gram. Most samples weighed between 200 and 800 grams.

Samples were then sieved for ten minutes, using a Ro-tap shaker and U.S. Standard Sieves. The sieve sizes used are shown in Table 1. After sieving, the fractions were examined for aggregates of finer particles, and any fractions which showed more than 25 percent aggregated grains were further disaggregated with a rubber stopper, and the sample was re-sieved. The fraction retained by the seven screens, plus the fines that passed the finest (4 phi) screen, were weighed on a digital Mettler balance to the nearest 0.1 gram, and the fraction weights recorded on data sheets. These procedures are

Table 1. Mesh sizes of sieves used for grain size analysis of sediments.

U.S. Standard Sieve Mesh Number	Millimeters	Phi Units*	Wentworth Size Class of Fraction Retained
5	4	-2	Pebble
10	2	-1	Granule
18	1	0	Very Coarse Sand
35	.5	1	Coarse Sand
60	.25	2	Medium Sand
120	.125	3	Fine Sand
230	.0625	4	Very Fine Sand
(pan)	$<.0625$	>4	Silt and Clay

* The phi unit is the negative of the log, base 2, of the size in millimeters.

modified slightly from Folk (1968).

Ambient Water Quality

Bacteriology. A water grab sample for determination of fecal coliform and fecal streptococcal bacteria was obtained at each station each sampling period by submersing a sterile BOD bottle with the mouth directed into the current. Samples were also obtained by this method weekly or at longer intervals at the Melmore and New Washington gaging stations on Honey Creek (Figure 1). Samples were immediately placed in ice and were returned to the laboratory, where they were processed within six hours. The samples were processed, plated, and counted in accordance with the methods prescribed in American Public Health Assoc. (1975) (Standard Methods, 14th Ed.) and Bordner et al. (1978). Representative colonies of the fecal streptococci from water samples collected at all eight locations on 1 August and 2 November 1979 were subjected to verification testing following Standard Methods. All colonies tested positive as fecal streptococci.

Chemical Parameters. The chemical quality of the water at the six upper Honey Creek stations and the two gaging stations was determined on grab samples collected in 1-L plastic bottles on 1 August and 2 November 1979, and 26 March and 14 July 1980. The parameters measured and the methods employed were as described below.

SUSPENDED SOLIDS (Residue Non-Filterable)

The sample is filtered through a pre-weighed glass fiber filter and the residue retained on the filter is dried to a constant weight at 103 - 105 C as described in Method 160.2 in Methods for Chemical Analysis of Water and Wastes, U.S. Environmental Protection Agency, National Environmental Research Center, Cincinatti, Ohio, 1979 (hereinafter referred to as EPA-600/4-79-020), pages 160.2-1 - 160.2-3.

SPECIFIC CONDUCTANCE

Specific conductance is measured using a Water Quality Laboratory conductivity meter (product of WQL) and a YSI cell. Samples are run at 25 C. This is in accordance with Method 120.1 in EPA-600/4-79-020, page 120.1-1.

pH

pH measurements are determined using a glass combination electrode with an Orion 701 digital pH meter. The samples are run at 25 C following the guidelines for Method 150.1 in EPA-600/4-79-020, page 150.1-1.

DISSOLVED ORTHOPHOSPHORUS (Modified Colorimetric Ascorbic)

For dissolved orthophosphorus the sample is filtered through a washed 0.45 micron pore size membrane filter. Automated colorimetric analysis follows using Method 365.1 from EPA-600/4-79-020, pages 365.1-1 - 365.1-9. The analysis is modified in that the method calls for a single mixed reagent. Instead, the ascorbic acid is used as a separate reagent and added directly to the analytical cartridge. This is done in order to increase shelf life of the reagent. The mixed reagent has a shelf life of about four hours while the shelf life of the separate reagents is at least 30 days. Distilled water is not used in the cartridge and the sample line size is doubled to improve sensitivity.

AMMONIA NITROGEN (Colorimetric Automated Phenate)

The sample is filtered through a 0.45 micron pore size membrane filter and analyzed using Method 350.1 from EPA-600/4-79-020, pages 350.1-1 - 350.1-6.

NITRATE AND NITRITE NITROGEN (Automated Cadmium Reduction)

Prior to analysis by cadmium reduction from Method 353.2 from EPA-600/4-79-020, pages 353.2-1 - 353.2-7, the samples are filtered through a 0.45 micron pore size membrane filter.

DISSOLVED SILICA

Samples are filtered prior to analysis through a 0.45 micron pore size membrane filter and analyzed colorimetrically using Technicon Industrial Method 105-71W from Technicon Industrial Systems Tarrytown, New York, February 1973.

TOTAL PHOSPHORUS

The sample undergoes a manual digestion using 11 N sulfuric acid and ammonium persulfate. If high turbidity is present after digestion the samples are filtered through a glass fiber filter and then analyzed using Method 365.1 from EPA-600/4-79-020, pages 365.1-1 - 365.1-9.

Phosphorus Loading from Tiro

The effect of phosphorus from septic tank effluents in the town of Tiro on stream phosphorus loading was measured on three occasions. These measurements were taken on 12 February, 27 February, and 23 April 1980. Stream flows were measured using a dye dilution technique (Water Research Association 1970). Water samples were collected at stations 3 and 4 and analyzed using the methods described above.

RESULTS

Biological Stream Community Investigations

Periphytic Algae. Algal taxa, densities, and percent occurrence from samples collected from upper Honey Creek, 1 August 1979 through 23 June 1980, are presented in Appendix Tables A.1 and A.2. Table A.3 is a cumulative list of all algal taxa identified during the study. (The appendix is available on request.)

Periphyton Abundance

Periphyton densities were highest in fall and lowest in early summer (Figure 3, Tables 2 through 5). Densities ranged from 223 cells / square millimeter (station 6) in the early summer of 1980 to a maximum of 130566 cells / sq mm (station 2) in the fall of 1979. Low densities in the early summer of 1980 were preceded by heavy precipitation over the sampling area, whereas highest densities were recorded from a period of low flow conditions.

Spatial as well as temporal differences in periphyton density were noted throughout the study. Densities from samples collected at stations 5 and 6 were generally much lower than those located further downstream. The stream reach along station 6 was covered by dense canopy on all collection dates. The stream channel and banks at station 5 were altered by a construction project midway through the study. Samples collected at stations 3 and 4, designed to detect input from the village of Tiro, Ohio (Figure 2), indicated elevated

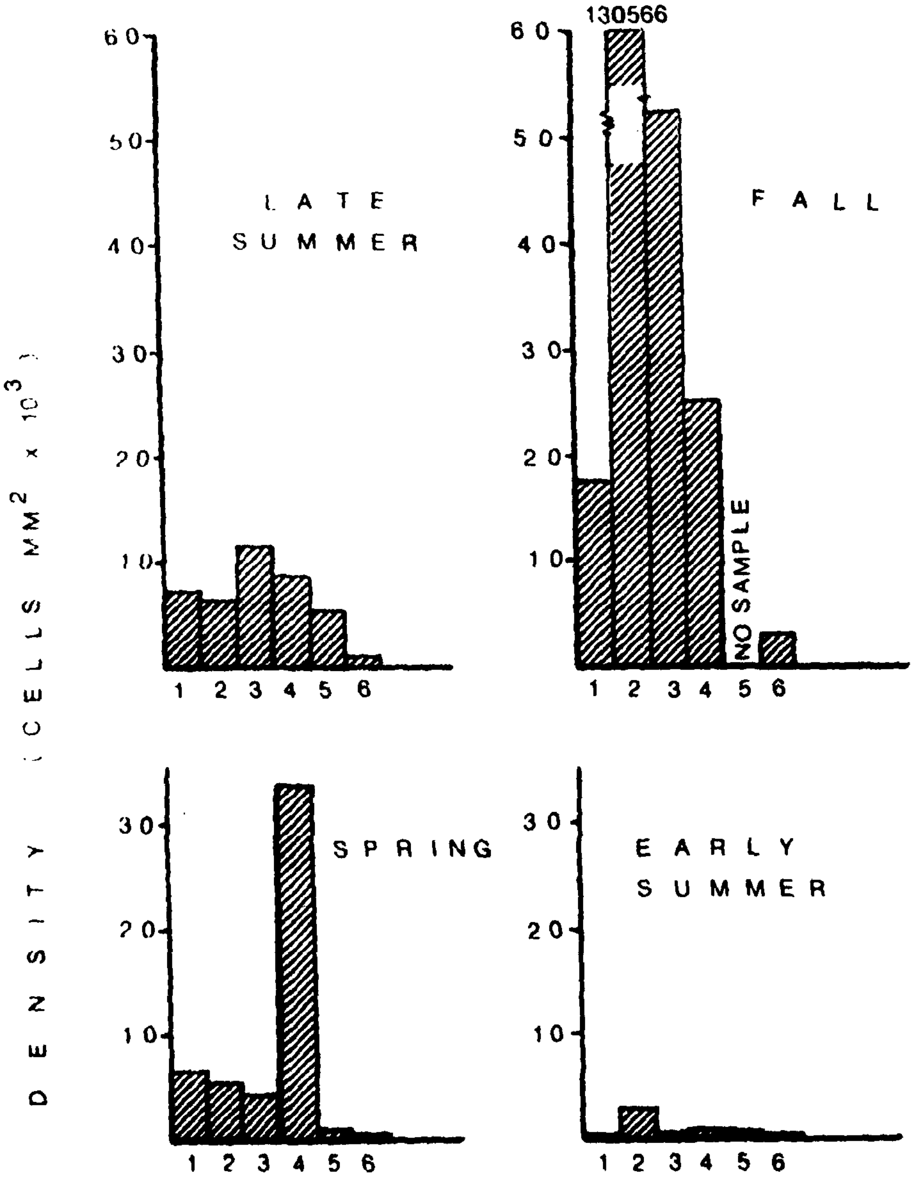

Figure 3. Total periphyton densities from samples collected from upper Honey Creek, 1 August, 1979 through 23 June, 1980.

Table 2. PERIPHYTON DENSITY AND PERCENT ABUNDANCE FROM SAMPLES COLLECTED FROM UPPER HONEY CREEK NEAR TIRO, OHIO, 1 August 1979

Taxon	Location	Density (Cells/Sq. mm)	Percent Abundance	Number of Taxa
BACILLARIOPHYTA	1	7444	100.00	35
CENTRALES		157	2.11	2
PENNALES		7287	97.89	39
TOTAL PERIPHYTON		7444	100.00	35
BACILLARIOPHYTA	2	6703	100.00	41
CENTRALES		48	0.72	2
PENNALES		6655	99.28	39
TOTAL PERIPHYTON		6703	100.00	41
BACILLARIOPHYTA	3	11563	100.00	34
CENTRALES		1926	16.66	4
PENNALES		9637	83.34	30
TOTAL PERIPHYTON		11563	100.00	34
BACILLARIOPHYTA	4	8650	100.00	20
CENTRALES		----	------	--
PEANNALES		8650	100.00	20
TOTAL PERIPHYTON		8650	100.00	20
BACILLARIOPHYTA	5	5375	100.00	29
CENTRALES		825	15.35	3
PENNALES		4550	84.65	26
TOTAL PERIPHYTON		5375	100.00	29
BACILLARIOPHYTA	6	1180	100.00	38
CENTRALES		24	2.03	4
PENNALES		1156	97.67	34
TOTAL PERIPHYTON		1180	100.00	38

Table 3. PERIPHYTON DENSITY AND PERCENT ABUNDANCE FROM SAMPLES COLLECTED FROM UPPER HONEY CREEK NEAR TIRO, OHIO, 16 November 1979

Taxon	Location	Density (Cells/Sq. mm)	Percent Abundance	Number of Taxa
BACILLARIOPHYTA	1	17498	100.00	33
CENTRALES		2130	12.17	4
PENNALES		15368	87.63	29
TOTAL PERIPHYTON		17498	100.00	33
BACILLARIOPHYTA	2	130566	100.00	34
CENTRALES		4512	3.46	2
PENNALES		126054	96.54	32
TOTAL PERIPHYTON		130566	100.00	34
BACILLARIOPHYTA	3	52560	100.00	26
CENTRALES		9357	17.80	2
PENNALES		43203	82.20	24
TOTAL PERIPHYTON		52560	100.00	26
BACILLARIOPHYTA	4	25378	100.00	28
CENTRALES		280	1.13	2
PENNALES		25090	98.87	26
TOTAL PERIPHYTON		25378	100.00	28
BACILLARIOPHYTA	6	3060	100.00	35
CENTRALES		43	1.41	2
PENNALES		3017	98.59	33
TOTAL PERIPHYTON		3060	100.00	35

Table 4. PERIPHYTON DENSITY AND PERCENT ABUNDANCE FROM SAMPLES COLLECTED FROM UPPER HONEY CREEK NEAR TIRO, OHIO, 22 April 1980

Taxon	Location	Density (Cells/Sq. mm)	Percent Abundance	Number of Taxa
BACILLARIOPHYTA	1	6700	100.00	14
CENTRALES		----	------	--
PENNALES		6700	100.00	14
TOTAL PERIPHYTON		6700	100.00	14
BACILLARIOPHYTA	2	5551	98.90	29
CENTRALES		21	0.37	1
PENNALES		5530	98.52	28
CHLOROPHYTA		41	0.73	1
EUSLENOPHYTA		21	0.37	1
TOTAL PERIPHYTON		5613	100.00	31
BACILLARIOPHYTA	3	4165	95.07	12
CENTRALES		----	-----	--
PENNALES		4165	95.07	12
CRYPTOPHYTA		216	4.93	1
TOTAL PERIPHYTON		4381	100.00	13
BACILLARIOPHYTA	4	34010	97.18	28
CENTRALES		246	0.70	1
PENNALES		33764	96.48	27
CRYPTOPHYTA		986	2.82	1
TOTAL PERIPHYTON		34750	100.00	29
BACILLARIOPHYTA	5	1213	100.00	31
CENTRALES		47	3.87	2
PENNALES		1166	96.13	29
TOTAL PERIPHYTON		1213	100.00	31
BACILLARIOPHYTA	6	302	100.00	21
CENTRALES		---	------	--
PENNALES		302	100.00	21
TOTAL PERIPHYTON		302	100.00	21

Table 5. PERIPHYTON DENSITY AND PERCENT ABUNDANCE FROM SAMPLES COLLECTED FROM UPPER HONEY CREEK NEAR TIRO, OHIO, 23 June 1980

Taxon	Location	Density (Cells/Sq. mm)	Percent Abundance	Number of Taxa
BACILLARIOPHYTA	1	378	100.00	24
CENTRALES		15	3.97	1
PENNALES		363	96.03	23
TOTAL PERIPHYTON		378	100.00	24
BACILLARIOPHYTA	2	3323	100.00	31
CENTRALES		26	0.78	1
PENNALES		3297	99.28	30
TOTAL PERIPHYTON		3323	100.00	31
BACILLARIOPHYTA	3	662	100.00	31
CENTRALES		6	0.91	1
PENNALES		656	99.09	30
TOTAL PERIPHYTON		662	100.00	31
BACILLARIOPHYTA	4	1004	100.00	30
CENTRALES		5	0.50	1
PENNALES		999	99.50	29
TOTAL PERIPHYTON		1004	100.00	30
BACILLARIOPHYTA	5	882	100.00	34
CENTRALES		17	1.93	2
PENNALES		865	98.07	32
TOTAL PERIPHYTON		882	100.00	34
BACILLARIOPHYTA	6	223	100.00	28
CENTRALES		4	1.79	2
PENNALES		219	98.21	26
TOTAL PERIPHYTON		223	100.00	28

standing crops on some collection dates. The sharpest differences were noted during the fall low stream flow conditions. However, on remaining collection dates, impact of any input was not discernible. Densities recorded during the spring of 1980 indicated higher densities upstream of the village. Although the variation in the periphyton standing crop in this segment of the upper Honey Creek sub-basin apparently precluded the evaluation of input from the village of Tiro, Ohio, the values demonstrate the potential for algal development within the low order streams.

Periphyton Composition and Principal Taxa

Five algal divisions, representing 120 taxa, were encountered during the study. These included Bacillariophyta (diatoms), Chlorophyta (green algae), Cryptophyta (cryptophytes), Cyanophyta (blue-green algae), and Eulenophyta (euglenoids).

A total of 108 diatom taxa were identified from the quantitative and qualitative samples. Other taxa included eight greens, two cryptophytes, four blue-greens, and two euglenoids. A total of 90 taxa were recorded from quantitative samples while 108 taxa were identified in qualitative samples. Of these, 78 taxa were common to both types of samples.

Diatoms dominated the periphytic communities of all sampling locations on all collection dates. No other algal division comprised more than five percent of the stream bottom periphyton communities at any time. Table 6 contains those

taxa comprising ten percent or more the standing crop at a given station during the study. All principal taxa were diatoms. The following discussion describes the occurrence and distribution of the principal taxa along with their ecological implications.

Cyclotella meneghiniana

This centric diatom was found throughout the sub-basin, but was most abundant in later summer and fall at the upstream stations. *C. meneghiniana* has been found throughout the Sandusky River Basin (Lowe and Kline 1975, Kline and Lowe 1975, Pryfogle 1975, and Stevenson 1975) and Ohio (Collins and Kolinsky 1977). This form is widely distributed in nature and apparently prefers nitrogen-rich waters and high conductivity (Lowe 1974). Its restricted occurrence within the study area implies some type of input at or below the village of Tiro.

Achnanthes Lanceolata var. dubia

This pennate diatom was found at nearly every location on all collection dates. This taxon apparently requires well aereated flowing waters and is never abundant under conditions of heavy organic enrichment (Lowe 1974). *A. lanceolata* var. *dubia* has been recorded throughout the Sandusky River Basin (Collins and Kolinsky 1977). The taxon was numerically abundant above and below the village of Tiro with the occurrence of other taxa which are indicative of nutrient enrichment.

Achnanthes minutissima

This taxon was widely distributed throughout the sub-basin, but was numerically important only at those stations where the periphyton standing crops were low. It is cosmopolitan in distribution, being indifferent to a wide range of environmental conditions, but is the best indicator of high oxygen concentrations in alkaline waters (Lowe 1974).

Diploneis elliptica

This taxon was generally restricted to the vicinity of the village of Tiro, Ohio. During late summer, *D. elliptica* was the dominant algal form at station 4 upstream from Tiro (6964 cells/sq mm). The occurrence of this taxon in Ohio has been rare, having been reported prior to this study only in Champaigne County (Collins and Kolinsky 1977). It is, however, considered to be cosmopolitan in distribution, and generally indicative of good water quality (Lowe 1974).

Table 6. Occurrence of principal algal taxa identified in quantitative samples collected from Upper Honey Creek near Tiro, Ohio, 1 August, 1979 through 23 June, 1980.

	Late Summer						Fall						Spring						Early Summer					
	Location						Location						Location						Location					
Taxon	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Bacillariophyta																								
Cyclotella meneghiniana			X[1]		X																			
Thalassiosira fluviatilus									X															
Achnanthes lanceolata			X			X																		
Achnanthes lanceolata var. *dubia*																		X						
Achnanthes minutissima																			X					
Diploneis elliptica				X																				
Gomphonema parvulum																	X						X	
Navicula cryptocephala		X			X		X	X	X	X					X	X			X	X	X	X		
Navicula cryptocephala var. *veneta*									X															
Navicula lanceolata		X																						
Navicula viridula							X						X	X	X	X	X		X	X		X		
Nitzschia filiformis	X																							
Nitzschia linearis	X							X				X												
Nitzschia recta								X																
Nitzschia palea																			X		X		X	X
Nitzschia sigmoidea	X																							
Surirella ovata					X	X						X	X	X			X	X	X				X	X

[1] Denotes occurrence of taxa comprising 10 percent or more of total algal density.

Gomphonema parvulum

This taxon was widely distributed throughout the study area and period. Maximum abundance was recorded upstream from the village of Tiro in early summer (2835 cells/sq mm). This species is considered to be a cosmopolitan species and may be an indicator of pollution (Lowe 1974).

Navicula cryptocephela

This pennate diatom was a principal taxon at most stations on all collection dates. It is a cosmopolitan species which is found over a wide range of nutrient and temperature conditions (Lowe 1974). Maximum abundance of this taxon was recorded in fall both above and below the village of Tiro.

Navicula cryptocephela var. veneta

This taxon was widely distributed throughout the study area and period. Maximum densities of N. cryptocephela var. veneta were observed from sampling stations downstream from the village of Tiro. It is considered to be a eutrophic form (Lowe 1977). It has been recorded from points throughout the Sandusky River Drainage Basin and Ohio (Collins and Kolinsky 1977).

Navicula Lanceolata

This taxon was generally distributed throughout the study area on most dates. It was recorded in highest abundance in fall from the village of Tiro and downstream. It is a cosmopolitan species, apparently prefers water of high mineral content, and is considered to be a eutrophic form (Lowe 1974). It has been reported (Collins and Kolinsky 1977) as widely distributed throughout Ohio.

Navicula viridula

This taxon was found at every station on all collection dates. Maximum occurrence of Navicula viridula was noted at Station 4 above Tiro in spring. It is a cosmopolitan species and considered to be indicative of eutrophic conditions (Lowe 1974). It has been reported to be distributed throughout the Sandusky River Basin and Ohio (Collins and Kolinsky 1977).

Nitzschia filiformis

This taxon was recorded only from later summer and fall collections. It was abundant only at stations 1 and 2, ranging up to 2820 cells/sq mm. This taxon, like many species of Nitzschia, is not fully autotrophic (Lowe 1974), and is probably cosmopolitan in distribution.

Nitzschia linearis

Although N. linearis was found at all locations on every collection date, maximum densities of this taxon were recorded from stations 1 through 4 in fall. It is a truly autotrophic species, cosmopolitan in distribution, but restricted to oxygen-rich water (Lowe 1974).

Nitzschia recta

Although it was generally distributed throughout the study area, N. recta was extremely abundant (37788 cells/sq mm) at station 2 in fall. It has been reported to be widely distributed throughout the Sandusky River Basin and Ohio (Collins and Kolinsky 1977). The ecological significance of this taxon is not well defined.

Nitzschia palea

This taxon was widely distributed throughout the study area. Maximum abundance of N. palea was recorded from station 2 in fall. This pennate form is considered to be a good indication of pollution (Palmer 1969) and can withstand a wide range of ecological conditions (Lowe 1974).

Nitzschia sigmoidea

N. sigmoidea is another cosmopolitan, eutrophic form (Lowe 1974) which was abundant only in fall. Maximum density of this taxon was noted at station 2 (8460 cells/sq mm). Distribution of this taxon was, however, patchy within the study area.

Surirella ovata

S. ovata was widely distributed throughout the study area on all collection dates. It became numerically important when total periphyton densities were low. This benthic form is common in winter months in the Sandusky River Basin, and is widely distributed throughout Ohio (Collins and Kolinsky 1977). It apparently can withstand a wide range of environmental conditions (Lowe 1974).

The majority of the principal taxa identifed during this study are cosmopolitan in distribution since they are able to develop under a wide range of chemical and physical conditions. Although some of the principal taxa identified in this study are considered to be indicators of pollution, their presence does not imply poor water quality within the study area. A review of the chemical data collected during the study period as well as the periphyton composition does, however, suggest nutrient enrichment. This situation is typical of streams receiving agricultural runoff. The periphyton standing crop values, along with field observations during the study period, suggest that the development of algae within this watershed is

not excessive. Apparently the nature of the substrates, moderate stream gradients, and frequent runoff events preclude high algal densities. Observations of periphyton communities in other streams receiving agricultural input, particularly those with very little gradient (drainage ditches) often show excessive algal mats developing under similar nutrient conditions.

Macrophytes. Aquatic macrophytes were found only during the August sampling period, and only at stations 2, 3, and 5. One or two specimens of *Potamogeton* sp. (pondweed) were present at stations 2 and 3, in areas where the current was sluggish. Several scattered individuals of *Potamogeton*, *Polygonum amphibium*, and *Alisma* sp. (water-plantain) were present in areas with moderate current along the entire sampling reach comprising station 5. *Typha* sp. (cat-tail) was restricted to a small riparian area just below station 5 at the downstream side of the bridge.

Macroinvertebrates. Table 7 lists the 94 invertebrate taxa identified from upper Honey Creek, and shows at which stations and seasons each was found. Many genera and species of aquatic oligochaetes and midgefly larvae were present but were not identified due to the large numbers present.

Table 7 confirms the need to collect invertebrate samples from all stream substrate types in order to obtain as many of the taxa present as possible. The qualitative samples

Table 7. List of invertebrate taxa identified from quantitative and qualitative samples from upper Kinney Creek in 1979-1980. An X beside a taxon indicates that it was found only in qualitative samples; a Q indicates that it was found only in quantitative samples. Sample periods for which each taxon was found are indicated by s (summer), f (fall), es (early spring), and ls (late spring). Parentheses around a sample period indicate that the taxon was found at that time only in quantitative samples.

Taxon	Station:	1	2	3	4	5	6
TURBELLARIA (flatworms)	X					es	
NEMATODA (roundworms)	Q	(f es ls)	(s f es ls)	(s f ls)	(f es ls)	(s f es ls)	(s f es ls)
OLIGOCHAETA (aquatic earthworms)		s f(es)ls	s f es ls	s f es ls	s f es ls	s f es ls	s f(es)ls
HIRUDINEA (leeches)					(f)	s f es ls	(es)
Helobdella stagnalis	Q					(s f ls)	(es)
GASTROPODA (snails)							
Ferrissia sp.		(s)	(s f)es	(f es)	(f es ls)		(s f es)ls
Gyraulus sp.	Q				(f)		
Lymnaea sp				s f	(f) ls	s(f)	
Physa sp.			s es ls	s f	s f es ls	s f es ls	s f es ls
Valvata sp.	Q	f					
BIVALVIA (clams)							
Pisidium spp.		(s f)	(s f)es ls	(s f es ls)	s(f es ls)	s f es(ls)	(s f es ls)
Sphaerium simile		s f(es ls)	s f es ls			s f(es)ls	(s)f es ls
Unionidae	Q						(es)
ISOPODA (sow bugs)							
Asellus (*forbesi*)[1]						s f es ls	es ls
AMPHIPODA (sideswimmers)							
Bactrurus mucronatus	X					es	
Crangonyx (?*setodactylus*)[1]				f es	f es ls	f es	
Hyalella azteca				f ls	(f) ls	s f(es)ls	
DECAPODA (crayfishes)		s ls	s es ls	s ls	s es ls	s es ls	s es ls
Orconectes rusticus	X	s ls			ls		s ls
Procambarus acutus acutus					?s	(?ls)	?f es
OSTRACODA (seed shrimps)	Q				(f)		(f)
HYDRACARINA (water mites)	Q	(f)					(es)
PLECOPTERA (stoneflies)		(s f ls)	(ls)		(s f)	(f)	
Allocapnia sp. (Capniidae)		es	es		f es		es
Amphinemura sp.	X	ls	ls				
Isoperla sp.	X		ls		ls		
TRICHOPTERA (caddisflies)							
Cheumatopsyche sp.		s f es ls	(s) es ls	s f es(ls)	s f es ls	(f)es	f es ls
Hydropsyche sp.		f ls		s ls	s(f) ls		
Limnephilus sp.	X		f				
Neophylax sp.	X				ls	ls	
?*Hydatophylax* sp.	Q		(f)				
Oecetis sp.	Q		(f)	(ls)	(f ls)	(f)	
Oligostomis sp.			es ls			(es)	
Pseudostenophylax sp.	X		es				
Ptilostomis sp.			(f)			f	
Rhyacophila sp.	X		es ls		es ls		es
HEMIPTERA (water bugs)							
Belostoma sp.	X			es			f
Corixidae			(s f)es ls	s	s f	s f	s f ls
Gerris sp.	X	ls	f es ls	ls	f es ls	s f es s	ls
Trepobates sp.	X			s	s		
Veliidae	X			?ls	?ls	?ls	s
EPHEMEROPTERA (mayflies)							
Baetis sp. (Baetidae)		f ls	ls	f ls	s	f	f ls
Caenis sp.		es(ls)		(s)			(f ls)
Callibaetis sp.	X				s		
Heptagenia sp.	Q		(s f)				(f)
Leptophlebia sp.		f es	f es ls	f	es	f	f es ls
Stenacron sp.	X	es ls			s		f ls
Stenonema sp.		f ls			s f es ls		ls

Table 7, continued.

Taxon	Station:	1	2	3	4	5	6
ODONATA (dragonflies, damselflies)							
Aeshna sp.	X		s ls	s f ls	s ls	s f	f
Boyeria sp.	X	ls	es ls				f
Calopteryx sp.		f ls	f ls	ls	f		f es ls
Gomphus sp.	X	s					s
Ischnura sp.	X			ls			s ?es ls
Tetragoneuria sp.	X		ls				
COLEOPTERA (beetles)							
Agabetes sp., larva	X			s	s		
Agabus sp., adult	X					s	
Agabus sp., larva	Q					(f)	
Anacaena sp., adult	X				s	s	
?Chrysomelidae, larva	Q					(s)	
Cranitis sp., adult	X				s		
Cyphon sp., larva	X		ls				
Dubiraphia sp., adult		ls	f ls		s(f)	s	s ls
Dubiraphia sp., larva		(f ls)	(s f es ls)	(f es)	(f es ls)	(s f ls)	(s f)es(ls)
Gyrinus sp., adult		es					
Haliplus sp., adult	X					s	
Helichus sp., adult	X	s	ls		?ls		
Helophorus sp., adult	X	ls			ls	ls	ls
?*Hydrochus* sp., adult	X	s					
Hydroporus sp., adult	X				s es ls	s es ls	s f ls
Hydroporus sp., larva	Q					(f)	
Ilybius sp., adult	X				s		
Macronychus sp., adult	X	ls	ls				
Microcylloepus sp., larva	X						f
Optioservus sp., larva	X	es					
Peltodytes sp., adult			ls	(s)	s	f ls	f ls
Psephenus sp., larva		(f)es ls					
Stenelmis sp., adult		s f ls			s es ls		
Stenelmis sp., larva		(s f es)ls		(ls)	s(f es)ls	(s)	(ls)
MEGALOPTERA (hellgrammites)							
Sialis sp.						s	s f es(ls)
DIPTERA (midges, craneflies, other flies)							
Ceratopogonidae, *Bezzia* complex		(f ls)	(s f es ls)	(s f es ls)	(s f)es ls	(s f es)ls	(s f)es(ls)
Chironomidae, larvae		s f es ls	s f es ls	s f es ls	s f es ls	(s)f es ls	(s)f es ls
Chironomidae, pupae		(s ls)	(s es ls)	(s f es)ls	s(f) ls	(f ls)	(es)ls
Dixidae, *Dixella* sp.	X				ls		
Dolichopodidae	Q			(s)	(f)		
Empididae		(f es)		(f) ls	(f)es ls	(f)	(es ls)
Muscidae, Fanninae	Q		(s)				
Psychodidae, *Pericoma* sp.	Q			(es)			
Psychodidae, *Psychoda* sp.	Q				(f)		
Simuliidae, *Simulium* sp.		ls	ls	s f ls	s ls	s(f)	es ls
Stratiomyidae			ls	(es)			
Syrphidae	Q			(es)		(s)	
Tabanidae			f es(ls)	f es	s(f) ls	(s f) ls	f(es)
Tipulidae, Eriopterini	Q				(es)		
Tipulidae, *Hexatoma* sp.[2]		(f)es ls		(f)			(es)
Tipulidae, *Pseudolimnophila* sp.	Q						(ls)
Tipulidae, *Tipula* sp.		es ls	es ls	es	(f)es		f
Tipulidae, unidentified	X		ls				
TOTAL TAXA[3]		40	43	39	54	45	48

[1]All representative adults which were examined were identified as the species shown; juveniles cannot be identified to species but were assumed to be the same species as the adults.

[2]Several individuals identified as *Hexatoma* sp. were probably *Pseudolimnophila* sp.

[3]Turbellaria and the separate crayfish species were not included in the enumeration because they were probably present at all sampling stations but were not adequately sampled by the methods used. Adult and larval stages of Coleoptera were enumerated as separate taxa because of their ecological differences.

generally were obtained from coarse substrates such as gravel and pebbles, and from substrate surfaces. These samples yielded 73 taxa. The quantitative samples were obtained from fine substrates such as sand and clay, and revealed 57 taxa. Of the total of 94 taxa, the qualitative and quantitative samples shared only 36 taxa.

Sorensen's Index of Similarity between communities (Pielou 1977) was computed based on the presence or absence of the taxa shown in Table 7. This index varies from 1.0 (communities identical) to 0.0 (communities share no taxa). The computations excluded Turbellaria and the separate crayfish species because they were probably present at all sampling stations but not adequately sampled by the methods employed. Also excluded were chironomid pupae and "Plecoptera", which consisted of stoneflies that were too damaged for further identification. Adult and larval beetles were included as separate taxa because they occupy distinctly different microhabitats and ecological niches.

Table 8 shows the values of Sorensen's Index for each pair of sampling stations in upper Honey Creek, based on both qualitative and quantitative samples. These values indicate that, on the basis of the invertebrates found, station 1, which was the highest order stream reach, was relatively dissimilar to the other stations except station 6. Stations 1 and 6 possessed the second highest similarity found. Station 6 showed a relatively high similarity to all of the other stations. Stations 3 and 4, which were reaches of the same

Table 8. Values of Sorensen's Index of community similarity between pairs of stations in the upper Honey Creek watershed, based on invertebrate taxa found during four sampling periods in 1979-1980. The index values were computed as SI = 2a/(2a + b + c), where a = taxa shared by stations i and j, b = taxa present only at station i, c = taxa present only at station j (Pielou 1977).

Station	1	2	3	4	5
2	.56				
3	.53	.56			
4	.56	.58	.69		
5	.42	.52	.62	.63	
6	.66	.59	.64	.65	.62

tributary about one km apart, possessed the highest similarity, despite any possible effects of the village of Tiro between them. All other pairwise comparisons were between different tributaries, which may account for their lower similarities.

The quantitative samples disclosed a large variation within stream reaches in the density and diversity of benthic invertebrates. In some instances, almost six times as many organisms were present in one grab sample as in the other taken on the same date at a given station (Tables 9 through 12). Much of this variation was undoubtedly due to the heterogeneous distributions of grain sizes in the substrates, as discussed in a following section. Because of this type of variation, a large number of samples would be needed to provide a precise estimate of the density of organisms in a given stream reach (Mason 1976).

Differences in density between some stream reaches were generally greater than differences within reaches. A two-way analysis of variance using log-10 transformed data revealed highly significant differences in the densities between stations, and significant differences in the densities between months, with no significant interaction between stations and months. Ninety-five percent confidence intervals showed that the densities differed significantly between stations 1 and 5, 4 and 5, and 4 and 6, and between the November and March sampling periods. The relatively low densities of invertebrates at station 1 (Table 13) were probably the result of a shifting substrate and frequent scouring events. At

Table 9. Number of individuals of each invertebrate taxon found in two quantitative Petersen dredge samples collected on 1 and 2 August 1979 at the six upper Honey Creek stations.

TAXA	Station	1		2		3		4		5		6	
	Sample	A	B	A	B	A	B	A	B	A	B	A	B
Nematoda (roundworms)				1	1	2				4	1	1	
Oligochaeta (aquatic earthworms)		1	3	15	441	80	21	2		256	504	101	117
Hirudinea (leeches)										23	2		
Helobdella stagnalis											1		
Gastropoda (snails, limpets)													
Ferrissia sp.			1	2									1
Lymnaea sp.										7	2		
Physa sp.										20	13		
Pulmonata								1					
Bivalvia (clams)													
Pisidium sp.			1	1	1	12	18	8		355	94	2	6
Sphaeriidae							1	5					
Sphaerium simile		2			2					34	18	7	83
Isopoda (sow bugs)													
Asellus (*forbesi*)										5	2		
Amphipoda (sideswimmers)													
Hyalella azteca										1			
Decapoda (crayfish)									1				
Plecoptera (stoneflies)		2						2					
Trichoptera (caddisflies											1		
Cheumatopsyche sp.		25	1	1									
Hemiptera (water bugs)													
Corixidae					2	2	1			5	1	1	
Ephemeroptera (mayflies)		1	1										
Baetidae								1					
Caenis sp.						1							
Hexagenia sp.					9								
Odonata (dragonflies, damselflies)										1			
Coleoptera (beetles)													
Chrysomelidae?, larva											1		
Dubiraphia sp., adult											1		
Dubiraphia sp., larva					3						2	6	7
Peltodytes sp., adult							1						
Stenelmis sp., adult		39						1					
Stenelmis sp., larva		18								1			
Megaloptera (hellgrammites)													
Sialis sp.										1		2	1
Diptera (midges, craneflies other flies)		6											
Ceratopogonidae, *Bezzia* complex					2		1	2		1			2
Chironomidae, larva		76	115	468	7	448	225	61	21	103	42	1	269
Chironomidae, pupa		1	3	1		10	8	3	1				
Dolichopodidae						1							
Muscidae, Fanninae					1								
Syrphidae										1			
Tabanidae								1			2		
TOTAL ORGANISMS		171	125	489	469	556	276	87	23	818	687	121	486
TOTAL TAXA		10	7	7	10	8	8	11	3	16	16	8	8
COMBINED TOTAL TAXA		12		13		11		12		22		10	

Table 10. Number of individuals of each invertebrate taxon found in two quantitative Ponar dredge samples collected on 2 and 8 November 1979 at the six upper Honey Creek stations.

TAXA	Station	1		2		3		4		5		6	
	Sample	A	B	A	B	A	B	A	B	A	B	A	B
Nematoda (roundworms)		6	1	9	1		5	3	1	3		1	1
Oligochaeta (aquatic earthworms)		34	13	77	325	71	92	2	7	303	262	5	607
Hirudinea (leeches)									1		7		
Helobdella stagnalis											2		
Gastropoda (snails, limpets)													
Ferrissia sp.					1		1	2	7				10
Gyraulus sp.									3				
Lymnaea sp.							1	2	10		1		
Physa sp.							1	2	72	5	26		
Valvata sp.		1											
Bivalvia (clams)													
Pisidium sp.			2	10	6	11	11		30	257	71	1	4
Sphaerium simile			1	1						73	42	36	56
Isopoda (sow bugs)													
Asellus (forbesi)										8	49		
Amphipoda (sideswimmers)													
Crangonyx (setodactylus?)									2		1		
Hyalella azteca							6		4		47		
Ostracoda (seed shrimps)									1			1	
Hydracarina (water mites)			1										
Plecoptera (stoneflies)		7							40	1			
Capniidae								1					
Trichoptera (caddisflies)					1								
Cheumatopsyche sp.		1				2	15		2	1			
Hydropsyche sp.									1				
Nyctiophylax? sp.					1								
Oecetis sp.				2				1		3			
Ptilostomis sp.					1						1		
Hemiptera (water bugs)													
Corixidae					2							4	1
Ephemeroptera (mayflies)				3	2	1		2		1			
Caenis sp.												1	
Hexagenia sp.					21							4	
Leptophlebia sp.					22						34		2
Stenonema sp.									2				
Odonata (dragonflies, damselflies)													
Calopteryx sp.					1								
Coleoptera (beetles)													
Agabus sp. larva											1		
Dubiraphia sp., adult									1				
Dubiraphia sp., larva			1	3	9	1	1	6	1	11	10	89	31
Hydroporus sp., larva											2		
Psephenus sp., larva		1											
Stenelmis sp., larva		17	1						23				
Diptera (midges, craneflies, other flies)					1	1		1					
Ceratopogonidae, Bezzia complex		15	1	1	3	7	15	2	2	6	1	46	1
Chironomidae, larva		280	184	245	23	190	730	362	997	346	101	38	79
Chironomidae, pupa						10	13	2	8	5			
Dolichopodidae									1				
Empididae		3					4		9		1		
Psychodidae, Psychoda sp.									3				
Simuliidae, Simulium sp.							1			1			
Tabanidae					2				2	4	4		
Tipulidae, Hexatoma sp.		2					25						
Tipulidae, Tipula sp.									1				
TOTAL ORGANISMS		366	205	351	422	294	923	388	1,230	1,108	663	226	880
TOTAL TAXA		11	9	9	17	9	15	13	26	16	19	11	10
COMBINED TOTAL TAXA		15		19		17		30		26		13	

Table 11. Number of individuals of each invertebrate taxon found in two quantitative Ponar dredge samples collected on 20 March 1980 at the six upper Honey Creek stations.

TAXA	Station 1 A	1 B	2 A	2 B	3 A	3 B	4 A	4 B	5 A	5 B	6 A	6 B
Nematoda (roundworms)	1		26	4				8		2	1	
Oligochaeta (aquatic earthworms)	7	1	38	207	9		6	21	948	158	83	35
Hirudinea (leeches)									4	1	1	
<u>Helobdella</u> <u>stagnalis</u>									2			
Gastropoda (snails, limpets)												
<u>Ferrissia</u> sp.			2	1		1	2	1			42	2
<u>Physa</u> sp.									38	2	1	
Bivalvia (clams)												
<u>Pisidium</u> sp.				14	27	24	1		168	7	121	2
<u>Sphaerium</u> <u>simile</u>	1			1					27	2	136	17
Unionidae												1
Isopoda (sow bugs)												
<u>Asellus</u> (<u>forbesi</u>)									3	7		
Amphipoda (sideswimmers)									1			
<u>Hyalella</u> <u>azteca</u>										1		
Decapoda (crayfish)												1
Hydracarina* (water mites)											1	1
Plecoptera (stoneflies)												
Capniidae								1				
Trichoptera (caddisflies)												
<u>Cheumatopsyche</u> sp.		1									3	
<u>Oligostomis</u> sp.									1			
Coleoptera (beetles)												
<u>Dubiraphia</u> sp., larva				4	1	1	1	1			199	40
<u>Stenelmis</u> sp., larva		4						1				
Megaloptera (hellgrammites)												
<u>Sialis</u> sp.												1
Diptera (midges, craneflies, other flies)												
Ceratopogonidae, <u>Bezzia</u> complex			1	22	1		1	1	2	1	133	46
Chironomidae, larva	32	55	191	520	283	24	52	120	19	25	320	27
Chironomidae, pupa				4	4						5	2
Empididae		3						6			1	
Psychodidae, <u>Pericoma</u> sp.					1							
Stratiomyidae					1							
Syrphidae					1							
Tabanidae				1							2	
Tipulidae, <u>Hexatoma</u> sp.		1									20	
Tipulidae, Eriopterini							2					
TOTAL ORGANISMS	41	65	258	778	328	50	65	160	1,213	206	1,069	175
TOTAL TAXA	4	6	5	10	9	4	7	9	11	10	16	12
COMBINED TOTAL TAXA	8		10		10		11		13		19	

Table 12. Number of individuals of each invertebrate taxon found in two quantitative Ponar dredge samples collected on 2 May 1980 at the six upper Honey Creek stations.

TAXA	Station 1 A	1 B	2 A	2 B	3 A	3 B	4 A	4 B	5 A	5 B	6 A	6 B
Nematoda (roundworms)		4		6	2	6	4	3	1	2		1
Oligochaeta (aquatic earthworms)	2	14	22	27	37	11	6	4	1,028	346	79	213
Hirudinea (leeches)									21	5		
Helobdella stagnalis									4	1		
Gastropoda (snails, limpets)												
Ferrissia sp.								1			4	2
Physa sp.							1		3	1		
Bivalvia (clams)												
Pisidium sp.			11	7	2	2	16	2	73	48	33	11
Sphaerium simile	1	1		3					15	32	153	22
Isopoda (sow bugs)												
Asellus (forbesi)									12	3		
Decapoda (crayfish)												
Procambarus acutus acutus									?1			
Plecoptera (stoneflies)		3	1	1								
Trichoptera (caddisflies)												
Cheumatopsyche sp.					1							
Oecetis sp.						1		1				
Hemiptera (water bugs)												
Corixidae												2
Ephemeroptera (mayflies)												
Baetis sp.				1								
Caenis sp.		1										1
Coleoptera (beetles)												
Dubiraphia sp., larva	4		1	1			1	1	1	2	117	52
Peltodytes sp., adult									1			
Stenelmis sp., larva		6			1	1					1	1
Megaloptera (hellgrammites)												
Sialis sp.												1
Diptera (midges, craneflies, other flies)												
Ceratopogonidae, Bezzia complex	5	1		7	13	10	3	2	5	2	8	12
Chironomidae, larva	84	401	96	91	99	87	40	87	17	20	107	166
Chironomidae, pupa	4	9	15	28	6	10	7	24	1	1	1	4
Empididae											1	
Simuliidae, Simulium sp.		1										1
Tabanidae				1						2		
Tipulidae, Hexatoma sp.		7										
Tipulidae, Pseudolimnophila sp.											1	
TOTAL ORGANISMS	100	448	146	173	161	128	78	125	1,183	465	505	489
TOTAL TAXA	6	11	6	11	8	8	8	9	14	13	11	14
COMBINED TOTAL TAXA	12		11		9		10		15		16	

Table 13. Numbers of invertebrates per square meter (N) and total number of taxa (T) identified from two Petersen or Ponar grab samples collected at each station each sampling period in 1979-1980.

Station		August	November	March	May
1	N	2,745	6,917	775	1,890
	N	2,006	3,875	1,229	8,467
	T	12	15	8	12
2	N	7,848	6,634	4,876	2,759
	N	7,527	7,976	14,704	3,270
	T	13	19	10	11
3	N	8,924	5,557	6,199	3,043
	N	4,430	17,445	945	2,419
	T	11	17	10	9
4	N	1,396	7,333	1,229	1,474
	N	369	23,398	3,024	2,363
	T	12	30	11	10
5	N	13,129	20,941	22,926	22,359
	N	11,026	12,531	3,893	8,789
	T	22	26	13	15
6	N	1,942	4,271	20,204	9,545
	N	7,800	15,120	3,308	9,242
	T	10	13	19	16

station 4, shifting and scouring probably caused smaller effects, while large stones and pebbles which underlay the surface sand and silt probably precluded higher population densities and caused difficulty in obtaining adequate grab samples. The high densities at station 5 apparently were due to the visibly greater organic (muck and detritus) component in the sediments there than elsewhere.

Tables 9 through 12 show that the Chironomidae (midgeflies) were the major contributors to the total density at each station each sampling period. At stations 2, 5, and 6, the Oligochaeta (aquatic earthworms and sludgeworms) shared numerical dominance with the chironomids, and at station 5 they far outnumbered other groups of organisms in March and May. The sphaeriid clams _Pisidium_ spp. or _Sphaeriium simile_ were numerically important contributors at station 3 in March, at station 5 in August and November, and at station 6 in August, March, and May. The only other organisms which were relatively abundant in the quantitative samples were caddisfly larvae (_Cheumatopsyche_ sp.) and adult beetles (_Stenelmis_ sp.) at station 1 in August; beetle larvae (_Dubiraphia_ sp.) at station 6 in November, March, and May; and biting-midge larvae (Ceratopogonidae) at station 6 in March.

Fishes. Table 14 lists the 12 fish species and the numbers of each collected at the six upper Honey Creek stations. The stoneroller minnow and the northern creek chub were the only two species found at all stations. The common

Table 14. Fishes identified from upper Honey Creek in samples taken during the summer (s), fall (f), early spring (es), and late spring (ls) of 1979-1980. Number of specimens of each species taken each sampling period provides a qualitative estimate of the relative abundances of the species.

Station	1				2				3				4				5				6			
	s	f	es	ls	s	f	es	ls	s	f	es	ls	s	f	es	ls	s	f	es	ls	s	f	es	ls
CATOSTOMIDAE																								
Catostomus commersoni commersoni (Lacepede) (common white sucker)				1	1	1		1		2				1		1								
CENTRARCHIDAE																								
Lepomis cyanellus (Rafinesque) (green sunfish)																		1			1	1		
CYPRINIDAE																								
Campostoma anomalum (stoneroller minnow)		10	1	9	8		2	5	3	7	6+	3		18	8+	4	1					1	1	
Notropis cornutus (common shiner)	15		5+	5				5						1							1		4	
Pimephales notatus (Rafinesque) (bluntnose minnow)	3	7		2	1			1										1			1		4+	
Rhinichthys atratulus meleagris Agassiz (western blacknose dace)					1	1	3	6	4	19	3+	3	7	12	4+	11								
Semotilus atromaculatus atromaculatus (Mitchill) (northern creek chub)	34	21	2	11	9	28	5+	3	14	19	4+	6	12	29	4+	6			1			6	5+	2
ESOCIDAE																								
Esox americanus vermiculatus LeSueur (grass pickerel)																								1+
PERCIDAE																								
Etheostoma blennioides (Raf.) (greenside darter)				2																				
Etheostoma flabellare flabellare Rafinesque (barred fantail darter)	1			2																				
Etheostoma nigrum nigrum (Raf.) (central Johnny darter)	1			3		6	4+	1													1	1	6+	2
Percina maculata (Girard) (blackside darter)		1																					1	
Total Species:	9				7				4				5				4				8			

white sucker, common shiner, and bluntnose minnow were collected at four stations. Stations 1, 2, and 6 revealed the most species, while stations 3, 4, and 5 revealed fewer species. No pattern in the distribution or abundance of the species was evident. However, the fish population at station 5 was depauperate, with only five individuals being seined throughout the year. It should be remembered that although the seining for fishes was fairly exhaustive, this technique provides an estimate only of those fishes which are readily caught by a seine, in areas where a seine can be effectively used. Electroshocking probably would have provided a more accurate picture of the relative numbers of each species and would have added more species to the list in Table 14.

Substrates

Table 15 reports the data generated by the grain size analysis. In the May sampling period, only two samples were taken at station 5. This locality had been channelized since the fall sampling period, making fall-spring comparisons of questionable value.

The data were plotted as weight percent histograms, cumulative percent diagrams, and in several other forms which facilitated analysis. Examples of one of these kinds of plots are reproduced in Figure 4; the remainder are available on request.

Comparison of total sample weight with the sum of the fraction weights shows little change in total sample weight due

Table 15. Grain size analysis of sediment samples from upper Rosey Creek. Four samples were taken at each of six stations in the fall and spring.

STATION NUMBER	SAMPLE NUMBER	DATE OF SAMPLING	TOTAL WEIGHT (GRAMS)	LARGER THAN -2 PHI	LARGER THAN -1 PHI	LARGER THAN 0 PHI	LARGER THAN 1 PHI	LARGER THAN 2 PHI	LARGER THAN 3 PHI	LARGER THAN 4 PHI	SMALLER THAN 4 PHI	TOTAL OF FRACTION WEIGHTS
1	1	2 NOV 1979	496.40	65.200	65.100	87.000	96.620	127.100	45.000	5.700	6.000	493.980
1	2	8 NOV 1979	393.20	3.300	[illegible]	[illegible].700	154.200	120.600	14.600	1.300	1.800	391.900
1	3	8 NOV 1979	676.70	163.700	[illegible].100	117.560	127.800	95.250	14.000	1.800	1.500	641.700
1	4	8 NOV 1979	373.00	270.200	40.700	[illegible].800	17.850	15.000	7.900	1.000	1.500	373.100
2	1	2 NOV 1979	317.50	134.850	45.400	41.500	44.600	33.500	14.850	5.500	5.750	327.300
2	2	8 NOV 1979	198.60	22.000	14.400	25.350	35.500	35.000	31.250	15.850	16.810	197.150
2	3	8 NOV 1979	420.70	1.500	5.400	15.200	81.250	175.600	97.000	24.900	15.610	420.750
2	4	8 NOV 1979	537.90	274.420	71.300	2.450	55.550	61.700	16.650	7.100	7.300	536.500
3	1	2 NOV 1979	602.20	230.100	4.200	35.600	68.500	116.700	30.900	5.050	5.900	600.850
3	2	8 NOV 1979	439.60	16.550	45.410	90.950	140.500	105.300	23.800	5.510	4.850	440.850
3	3	8 NOV 1979	489.90	158.70	61.100	38.450	73.710	77.100	12.150	15.450	4.200	490.400
3	4	8 NOV 1979	662.40	127.520	143.100	171.200	137.200	61.950	13.050	13.700	2.700	670.720
4	1	2 NOV 1979	192.40	85.750	37.400	31.000	22.900	9.500	3.900	1.400	2.300	193.850
4	2	8 NOV 1979	267.20	200.600	13.400	11.700	12.700	[illegible]	7.400	1.955	1.900	266.050
4	3	8 NOV 1979	277.20	44.550	41.050	51.300	49.600	40.100	74.000	11.000	15.650	277.250
4	4	8 NOV 1979	241.30	168.200	24.550	13.150	11.600	15.600	5.300	1.100	1.650	240.550
5	1	2 NOV 1979	52.70	.000	1.550	8.450	9.000	7.750	6.050	6.050	11.600	52.450
5	2	8 NOV 1979	89.10	1.000	5.900	11.050	17.850	25.350	15.350	6.350	5.150	88.600
5	3	8 NOV 1979	236.10	.650	4.250	40.450	43.000	34.250	29.150	23.950	58.750	234.450
5	4	8 NOV 1979	48.20	.000	1.550	5.800	9.050	5.550	5.750	5.050	11.850	47.800
6	1	2 NOV 1979	336.10	101.400	44.650	37.650	32.350	38.650	39.950	19.000	20.750	334.600
6	2	8 NOV 1979	526.30	255.050	62.350	56.450	45.400	37.250	17.650	9.055	6.350	519.550
6	3	8 NOV 1979	276.70	27.700	37.650	35.650	29.650	41.450	44.750	22.650	35.950	275.450
6	4	8 NOV 1979	416.70	3.500	36.950	74.650	76.250	76.350	53.350	29.750	61.550	414.350
1	1	2 MAY 1980	625.30	394.860	55.680	75.070	62.080	47.640	16.080	2.660	2.970	697.040
1	2	2 MAY 1980	636.20	35.500	93.440	159.340	156.450	137.320	47.910	4.780	4.480	639.220
1	3	2 MAY 1980	728.40	411.420	64.100	53.700	46.270	47.200	51.760	13.130	10.650	728.990
1	4	2 MAY 1980	423.90	201.120	66.610	48.030	35.060	51.960	27.200	7.010	4.470	455.660
2	1	2 MAY 1980	399.80	56.800	44.260	81.640	115.530	52.770	24.720	10.790	13.290	400.220
2	2	2 MAY 1980	620.30	208.980	64.070	139.900	127.020	71.170	26.970	12.590	13.750	629.450
2	3	2 MAY 1980	639.20	69.260	84.660	117.660	152.650	123.970	54.330	18.080	16.750	639.400
2	4	2 MAY 1980	535.00	54.360	26.200	65.180	116.770	125.410	79.360	35.320	35.460	538.060
3	1	2 MAY 1980	554.70	77.760	66.820	58.840	127.720	127.310	26.470	6.110	10.690	555.720
3	2	2 MAY 1980	318.30	139.160	54.240	50.200	31.910	21.420	8.010	3.470	5.270	313.680
3	3	2 MAY 1980	578.10	312.420	60.760	55.940	51.710	48.190	16.040	4.750	6.090	575.900
3	4	2 MAY 1980	375.80	196.220	37.570	26.720	38.070	52.940	18.480	3.220	3.510	376.730
4	1	2 MAY 1980	422.20	67.350	36.170	30.640	50.050	99.160	67.460	89.100	37.810	417.780
4	2	2 MAY 1980	353.50	265.01	16.250	17.560	19.300	16.900	10.140	6.920	6.840	360.920
4	3	2 MAY 1980	465.70	230.420	37.110	47.440	44.470	42.760	14.940	6.160	9.880	453.200
4	4	2 MAY 1980	392.80	107.35	39.370	47.570	78.120	60.650	23.800	7.960	11.020	391.850
5	1	2 MAY 1980	396.50	21.160	20.030	46.590	104.800	106.510	50.240	20.190	27.120	396.640
5	2	2 MAY 1980	524.20	22.440	34.260	52.920	80.130	137.000	51.490	43.190	64.820	516.470
6	1	2 MAY 1980	614.20	229.880	110.760	84.530	77.570	72.580	39.930	13.410	18.740	713.370
6	2	2 MAY 1980	524.10	215.250	72.160	51.330	63.770	67.950	31.150	9.960	12.760	524.330
6	3	2 MAY 1980	406.10	54.[illegible]	54.860	63.470	66.020	75.650	49.790	17.350	24.570	405.770
6	4	2 MAY 1980	226.30	3.05	15.010	36.920	37.250	46.220	36.060	17.100	33.330	225.040

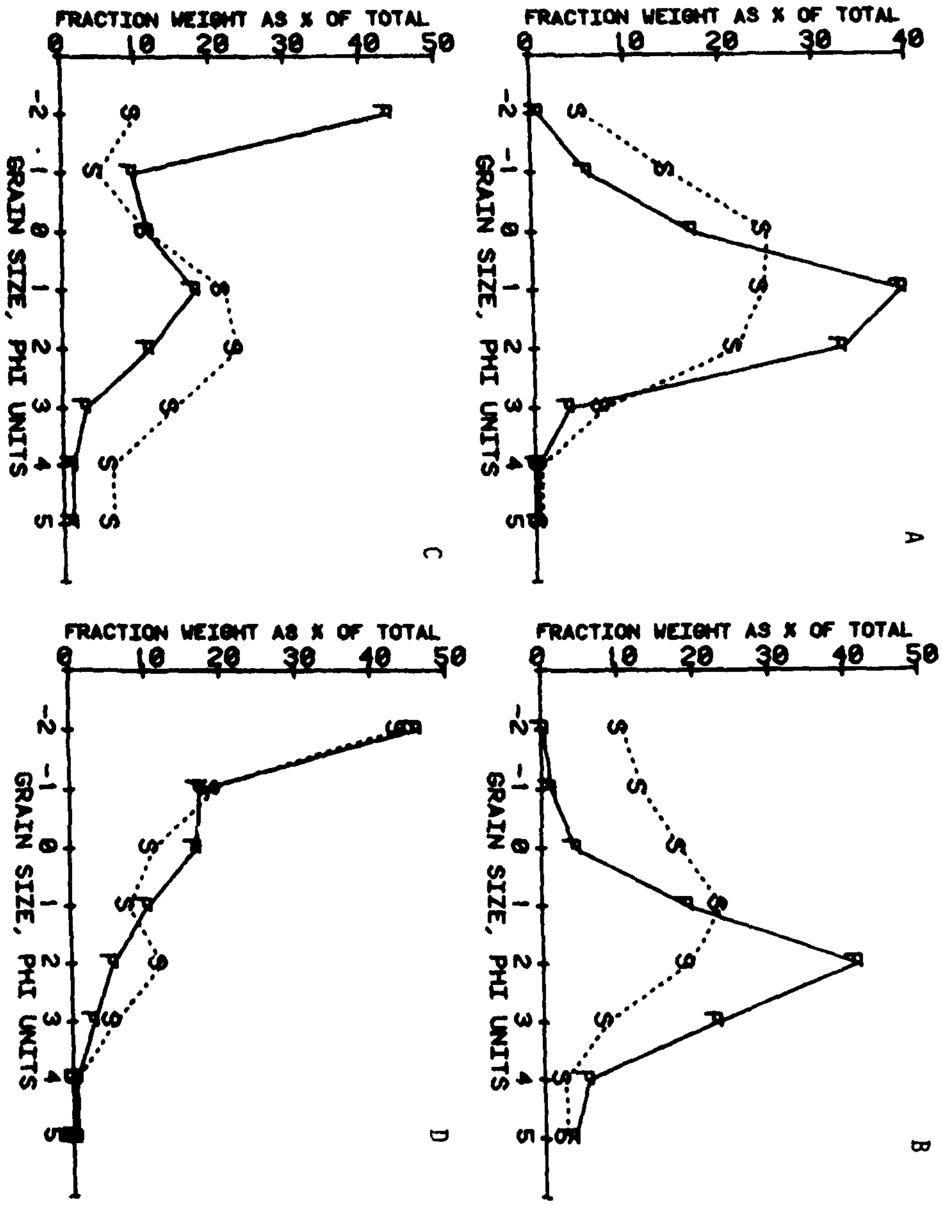

Figure 4. Representative plots of grain size distribution. Fall samples are plotted using a solid line and the symbol F; spring samples are plotted with a broken line and the symbol S. Plots A and B show coarser spring samples. Plot C shows a coarser fall sample. Plot D was judged unchanged between fall and spring.

to changes in moisture content or retention of grains by the sieves.

Ambient Water Quality

Bacteriology. The concentrations of fecal coliforms and fecal streptococci, and the ratios of fecal coliforms to fecal streptococci, are shown in Table 16 for the six upper Honey Creek stations, and in Table 17 for the Melmore and New Washington gaging stations. For general contact recreational water, national water quality criteria require a log-mean (geometric mean) per 30 days of fewer than 1000 fecal coliforms per 100 ml, with a maximum of 2000/100 ml per 30 days in 10 percent of the samples. For primary contact recreational waters, a log-mean/30 days of fewer than 200/100 ml with a maximum of 400/100 ml per 30 days in 10 percent of samples is required. For use as a public water supply, a log-mean of fewer than 2000 fecal coliforms/100 ml is required, and for use as agricultural water, a monthly mean of fewer than 1000 (Bordner et al. 1978). Ohio EPA water quality standards (OAC-3745-1) require a log-mean fecal coliform content (at least five samples per 30 days) of 200/100 ml or fewer, and not to exceed 400/100 ml in more than 10 percent of samples taken in any 30 day period.

The frequency of sampling during this pilot study was not large enough to permit application of the above water quality criteria. However, from the samples obtained, the evidence is strong that at times fecal coliforms at every station exceeded

Table 16. Concentrations of fecal coliforms (FC) and fecal streptococci (FS), and FC/FS ratios, at the six upper Honey Creek stations on four dates.

Station		Fecal Coliforms/100ml	Fecal Streptococci/100ml	FC/FS
		1 August 1979		
1		180	690	0.26
2		1,150	1,800	0.64
3		4,800	1,170	4.10
4		3,600	2,500	1.44
5		5,000	840	5.95
6		420	1,140	0.37
		2 November 1979		
1		480	1,620	0.30
2		106	860	0.12
3		10,900	4,700	2.32
4		260	970	0.27
5		1,040	6,800	0.15
6		9,300	14,600	0.64
		27 March 1980		
1		2,370	1,040	2.28
2		410	1,040	0.39
3		8,200	1,000	8.20
4		130	160	0.81
5		200	258	0.78
6		740	670	1.10
		24 June 1980		
1	(Stations 1-4 & 6 only slightly turbid)	470	2,200	0.21
2		1,600	630	2.54
3		8,100	3,200	2.53
4		790	4,500	0.18
5	(Water very turbid)	56,000	42,000	1.33
6		3,900	1,260	3.10

Table 17. Concentrations of fecal coliforms (FC) and fecal streptococci (FS), and FC/FS ratios, at the Melmore (MEL) and New Washington (NW) gaging stations. FC/FS ratios were not calculated when fewer than 98 FS/100 ml were present.

Date	Turbidity	Fecal Coliforms per 100 ml		Fecal Streptococci per 100 ml		FC/FS	
		MEL	NW	MEL	NW	MEL	NW
1 August 1979		18,000	230	47,000	640	0.38	0.36
2 November 1979		450	370	210	2,100	2.14	0.18
12 November 1979		2,100	760	9,000	1,120	0.23	0.68
26 November 1979	very turbid	5,100	6,500	38,000	102,000	0.13	0.06
3 December 1979	clear	660	640	220	830	3.00	0.77
17 December 1979	clear	260	240	< 100	< 100		
8 January 1980	clear	210	150	170	130	1.23	1.15
14 January 1980	turbid	1,290	1,110	2,200	2,500	0.59	0.44
21 January 1980	clear	59	540	90	103		5.24
28 January 1980		165	44	32	30		
4 February 1980		700	710	137	98	5.10	7.24
12 February 1980		730	360	970	62	0.75	
18 February 1980		86	330	51	30		
10 March 1980	very turbid	4,000	2,300	7,600	5,500	0.53	0.42
7 April 1980	very turbid	1,370	850	560	480	2.45	1.77
14 April 1980		3,200	2,100	8,400	6,400	0.38	0.33
21 April 1980	slighty turbid	380	200	390	65	0.97	
28 April 1980	slighty turbid	740	200	76	110		1.82
12 May 1980		600	490	390	290	1.54	1.69
24 June 1980	slighty turbid	545	480	1,560	1,160	0.35	0.41

all of the criteria for water quality. In general, as indicated by the greater number of samples at the New Washington and Melmore stations, bacterial concentrations (both fecal coliforms and fecal streptococci) increased dramatically with turbidity (runoff), and decreased as the streams returned to median levels and became clear.

Fecal streptococci data, in conjunction with fecal coliform data, are useful for indicating the source of fecal pollution. Fecal streptococci counts were used to compute ratios of fecal coliforms to fecal streptococci. A ratio over 4.0 is regarded as evidence of contamination from human body wastes; a ratio below 0.7 suggests pollution derived entirely or predominantly from livestock or poultry wastes, milk and food processing wastes, or stormwater runoff. Intermediate values of the ratio represent a mixture of human and non-human sources, assuming that the samples were taken not more than 24 hours flow time from the point of pollution (Bordner et al. 1978).

The ratios computed for upper Honey Creek (Table 16) indicate human fecal pollution in August 1979 at stations 3 (below Tiro) and 5, and in March 1980 again at station 3. Stations 1, 2, 4, and 6 showed pollution of either mixed origin or non-human origin on all four sampling dates. Pollution of human origin was evident at the New Washington gaging station only on two dates, in January and February 1980, and at the Melmore station only once, in February. These latter two stations may be more subject than the upstream stations to a

long travel time from the origin of pollution, and thus the high ratios may reflect the faster rate of disappearance of viable fecal streptococci than fecal coliforms from the water column.

Chemical Parameters. Chemical concentrations are shown in Table 18 for the four sampling dates. Phosphorus was measured as total phosphorus and dissolved reactive phosphorus. On all four sampling dates, dissolved reactive phosphorus concentrations were from two to four times higher at station 3 than at the next highest station. The highest dissolved reactive phosphorus values for most of the stations occurred in the August 1979 samples. Station 3 also possessed total phosphorus values which were two to three times higher than at any other station in three of the four sets of samples, whereas station 6 always possessed the second highest concentrations except in March, when it had the highest value. Overall, the data indicate elevated phosphorus levels most of the time at station 3 in relation to the other upper Honey Creek stations.

Nitrogen was measured as nitrate + nitrite, and ammonia nitrogen. No station had consistently higher nitrate + nitrite values than the other stations. The highest values of nitrate + nitrite for most stations were found in March. Nitrate + nitrite levels at three stations in March approached the Ohio EPA standard (OAC-3745-1) of 10 mg/L nitrate (N) for public water supply intakes, but were well below the agricultural standard of 100 mg/L. Station 3 possessed the highest ammonia

Table 18. Chemical concentrations measured from water grab samples collected at the six upper Honey Creek stations and the New Washington (NW) and Melmore (ME) gaging stations. All values except pH and conductivity are reported in ppm.

Station	Ortho-Phosphates	Total Phosphorus	Suspended Solids	Nitrates + Nitrites	Ammonia	Conductivity (µmhos/cm)	pH	Silica
1 August 1979								
1	0.042	0.069	12.5	0.25	0.010	752	8.15	11.05
2	0.010	0.032	9.9	0.11	0.041	770	7.77	11.57
3	0.415	0.450	2.9	0.48	0.089	805	8.04	6.82
4	0.026	0.058	7.9	0.12	0.039	727	8.13	9.59
5	0.039	0.089	7.4	0.43	0.255	774	7.74	17.04
6	0.095	0.158	6.8	0.32	0.049	810	8.05	12.71
NW	0.043	0.077	21.7	0.19	0.005	759	8.18	10.76
ME	0.096	0.599	410.0	1.68	0.032	402	8.01	4.62
2 November 1979								
1	0.005	0.047	4.4	0.60	0.018	761	7.95	6.08
2	0.028	0.050	0.2	1.47	0.014	763	7.77	8.57
3	0.192	0.274	4.3	1.26	0.066	745	7.90	8.71
4	0.066	0.109	0	1.37	0.013	704	7.90	9.17
5	0.010	0.084	7.7	4.45	0.023	782	7.55	13.99
6	0.033	0.154	13.7	4.54	0.331	745	7.66	10.78
NW	0.012	0.043	3.3	0.73	0.008	758	8.02	5.90
ME	0.011	0.050	1.3	1.34	0.009	718	8.22	2.51
26 March 1980								
1	0.016	0.174	64.2	5.33	0.004	522	7.90	6.55
2	0.004	0.038	12.4	7.60	0.008	641	7.97	6.13
3	0.040	0.083	5.5	7.08	0.090	619	8.01	5.97
4	0.010	0.032	4.6	7.79	0.006	601	8.07	5.40
5	0.005	0.143	61.9	3.99	0.007	489	7.45	6.21
6	0.020	0.249	93.3	4.92	0.012	462	7.55	6.81
14 July 1980								
1	0.016	0.098	38.3	1.21	0.004	685	8.25	9.21
2	0.003	0.046	18.5	0.90	0.001	601	8.18	8.95
3	0.297	0.479	6.1	2.23	0.204	794	8.04	8.01
4	0.012	0.052	15.0	4.40	0.018	672	8.05	7.94
5	0.005	0.078	13.2	1.13	0.108	721	8.03	12.35
5 Rep.	0.004	0.078	15.3	1.14	0.040	728	8.01	12.39
6	0.065	0.153	26.8	1.99	0.108	680	7.95	9.03

levels in March and July, and the second highest levels in August and November.

Suspended solids, conductivity, pH, silica, sulfate and chloride showed no pattern among the stations. However, conductivity appeared to decrease during periods of runoff, as indicated by simultaneously elevated concentrations of suspended solids (for example, see Table 17, March 1980). The water at all stations was slightly alkaline, with a pH between 7.45 and 8.25 throughout the year.

Tiro Phosphorus Loading Study

Table 19 provides a sample of the type of data used to calculate the phosphorus loading from Tiro. The flows downstream (station 3) and upstream (station 4) from the town were measured during the midpoint of the chemical sampling time. Average concentrations were used to estimate stream transport above and below the town, with the increment in loading attributed entirely to septic effluents. Three such sets of measurements indicated loading rates of 0.12 kg/day on 12 February 1980, 0.27 kg/day on 27 February 1980, and 0.24 kg/day on 23 April 1980. For the 27 February collection, soluble orthophosphorus, and ammonia nitrogen were measured in addition to total phosphorus (Table 20). The large increases in soluble phosphorus and ammonia are typical of the impact of sewage effluents on stream water quality.

Table 19. Data for calculation of Total Phosphorus loading from Tiro, 23 April 1980.

Sampling Time	Total Phosphorus Concentration (mg/ℓ) Station 4	Station 3
2:00 PM	0.012	.139
3:00 PM	0.015	.164
4:00 PM	0.015	.206
5:00 PM	0.015	.211
6:00 PM	0.015	.185
7:00 PM	0.015	.162
8:00 PM	0.015	.128
Stream Flow - 5:00 PM	9.3×10^{-3} m^3/sec.	1.8×10^{-2} m^3/sec.

Table 20. Effects of Tiro on soluble reactive phosphorus, total phosphorus and ammonia concentrations on 27 February 1980.

Sampling Time	Soluble Reactive Phos. mg/ℓ		Total Phosphorus mg/ℓ		Ammonia mg/ℓ	
	St. #4	St. #3	St. #4	St. #3	St. #4	St. #3
9:30	.033	.079	.035	.095	.011	.190
10:30	.037	.083	.036	.102	.010	.210
11:30	.033	.075	.032	.098	.023	.215
12:30	.030	.085	.032	.106	.005	.265
1:30	.030	.105	.035	.177	.000	.278
2:30	.030	.132	.036	.171	.002	.379
3:30	.036	.123	.041	.199	.004	.335
4:30	.036	.129	.042	.216	.001	.374

DISCUSSION

Limitations of the Study Approach

The results presented in this study represent preliminary data and as such provide the basis for initial interpretation and characterization of the environmental quality of the six upper Honey Creek stations. Because the number of samples obtained for investigating each parameter was minimal, one should refrain from drawing conclusions which may not be accurate when based on such limited data. Particularly vulnerable from this standpoint would be characterizations of the bacterial and chemical water quality based on only the four sets of samples obtained during this pilot study. The data obtained, however, do provide important baseline information representative of non-storm conditions which can guide further investigative efforts. The data derived from the four sets of biological (algal, invertebrate, and fish) samples are more adequate for characterizing the study sites because the organisms inhabit the sampling locations for relatively long periods of time (weeks or months) and thus by their persistence or absence reflect the water or sediment quality integrated over those time intervals. The bacterial and chemical samples reflect only the conditions existing at the point in time of sampling.

Several limitations of the sampling methods became obvious during this study, and further investigations of upper Honey Creek or similar streams would be enhanced by incorporating the

changes described here. The Ponar dredge is a standard and effective device for sampling invertebrates from sedimentary substrates, as it proved to be in the present study. However, in upper Honey Creek the grain sizes of the substrates in almost all samples were such that only a small amount of the total sample could be sieved through the No. 30 mesh screen. This required transporting the majority of the substrate to the laboratory, where the very time-consuming effort of hand picking the unconcentrated invertebrates from large quantities (as much as 4 L) of substrate was accomplished. The results of the paired samples at each station demonstrated a very large spatial variation in the abundance of invertebrates in the substrates, probably due partly to the different sediment types sampled within each station reach. Therefore, to obtain a more precise estimate of the overall densities of benthic invertebrates, and simultaneously to reduce the cost and time involved in processing samples, a larger number of samples of considerably smaller volume than obtained by the Ponar dredge should be collected. A coring device with a small cross-sectional area (about 5 cm diameter) would probably suffice.

As previously stated, a more accurate estimate of the fish species present at the stations would be obtained by supplementing seining efforts with electroshocking. It is possible, however, that few or no additional species would be obtained from these first and second order streams, which can be completely blocked by stretching the seines across the

stream. The greatest advantage of electroshocking would be in collecting fish hiding in debris or deep holes, and in providing a better estimate of relative numbers of each species.

Several problems were encountered during substrate sampling and processing which suggest changes in approach. At several stations, the sediment included many particles of large pebble size (32 mm) and larger. Several samples included rocks up to 10 cm in diameter. One such rock may represent half the total weight of a 250 gram sample. Such a sample cannot reliably be used to draw conclusions about the substrate it "represents." Prohibitively large samples would be required in these cases.

Another sampling-related problem is the thinness of the deposits in many first order streams. Frequently, samples included some glacial till from the stream bed below the deposit which was visible on the surface. These samples are a misleading mixture of an erodable but resistant bed material and stream deposits. They represent two very different environments. Also, the till tends to disaggregate poorly, producing size frequency results of uncertain meaning.

We encountered further difficulty at station 5, which was extensively cleared, landscaped, and then channelized between fall and early spring sampling periods. The May samples appeared to be almost entirely of disturbed bed material rather than natural stream deposits.

Station Comparisons

Despite the limitations in the sampling methods and data discussed above, a number of legitimate comparisons and interpretations are possible. Our visual observations and data on the substrates suggest several conclusions. One quickly observes that the substrates are very variable, forming a mosaic of patches of different grain-size characteristics. At most stations, the stream bed was composed of a complex mixture of sand and gravel, fine sediment often with entrapped organic debris, muddy sand, and glacial till. It would not be possible to characterize any such stream bottom as a whole except by describing it as variable.

On the other hand, there are differences between stations. Station 5 had organic-rich deposits which were almost devoid of coarse material. Stations 1 and 3 were dominated by sand and gravel with relatively little included fines, and at low water were essentially braided streams in miniature. Station 4 had very thin deposits as a veneer over glacial till. Stations 2 and 6 were generally siltier than 1 and 3, but coarser than 5.

The most interesting conclusion comes from examining the pairs of samples taken spring and fall at the same spot. One might expect that spring samples, subjected recently to high flows of spring runoff, would be coarser grained than fall samples, with a recent history of relatively low velocity flows. The data were plotted in pairs, in weight percent form; examples are in Figure 4. Of 22 pairs, the spring samples were coarser in nine cases, and finer in four cases. Nine cases

either were essentially unchanged or showed ambiguous changes. These results seem to show the expected seasonal adjustment of sediment grain size distributions to hydrologic conditions in the stream. However, the pattern is often obscured by other sources of variability.

The changes in grain size distribution which might accompany no-till farming could only be detected if these other sources of variation could be controlled or accounted for. We do not believe that such long-term changes could be reliably detected using the approaches employed in this pilot study.

From the occasionally elevated concentrations of fecal coliform bacteria, the high ratio of fecal coliforms to fecal streptococci, and the elevated levels of phosphorus and occasionally nitrogen, at station 3 as compared to the other stations, there appears to be a definite, observable influence on stream water quality by nonpoint sources in the Tiro vicinity. Whether or not these sources are septic tank effluents remains to be determined by more extensive sample analysis over more frequent intervals than in this pilot study. An effort was made in choosing all of the stations to avoid their proximity within several hundred meters to obvious septic tank or tile effluents. Nevertheless, the fecal coliform counts indicated that human or animal fecal pollution may be a substantial problem needing resolution at all six stations if any desired water use is to be safely obtained from any of these upper Honey Creek tributaries.

In general, the invertebrate samples indicated good stream

quality at all stations. A one-way analysis of variance showed that there was no statistical difference at the 95 percent confidence level in the number of taxa at the six stations. Among the taxa found, several are considered to belong to "indicator" groups. Notably, various genera of mayflies, which are sensitive to depressed dissolved oxygen levels which often accompany organic enrichment, were present at all stations. Stoneflies, which comprise another enrichment-sensitive group, were present during at least one sampling period at every station except station 3, below Tiro. No invertebrates whose presence in large numbers indicates pollution or enrichment were found in disproportionately large numbers. One unexpected invertebrate was found, however. Several individuals of the amphipod crustacean *Bactrurus mucronatus*, a subterranean species, were collected in the early spring qualitative sample at station 5. This station was situated about 200 m downstream from two tile system effluents. It seems probable that this species normally populates tile systems and is occasionally washed from these systems into the receiving streams.

The results of this study provide strong evidence which suggests that substrate type exerts an overriding influence over other chemical and physical factors in determining the nature of the biological community which is present in a given stream reach in upper Honey Creek. Comparison of the density of invertebrates in the quantitative samples with the sediment type at each station (Table 21) suggests that a relationship exists wherein stations with predominantly fine-grained

Table 21. Mean number of benthic macroinvertebrates per sample (N=8) for each upper Honey Creek station compared to the predominant sediment type at each station.

Station	Sediment Type	Mean/Sample
5	organic-rich, devoid of coarse material	793
2	siltier than 1 and 3; coarser than 5	386
6	siltier than 1 and 3; coarser than 5	484
1	sand and gravel	190
3	sand and gravel	340
4	fine deposits as veneer over glacial till	271

sediments possess the highest invertebrate densities, and those with predominantly large-grained sediments (sand and gravel) possess the lowest densities. This relationship exists because the numerically dominant invertebrates at all of the upper Honey Creek stations are burrowing midgefly larvae and/or oligochaetes; as grain size increases, less habitat suitable for burrowing is available. Furthermore, the presence of fine-grained substrates is indicative of a stable sedimentary substrate which permits the colonization and persistence of those invertebrates which live within the sediments as well as of aquatic macrophytes such as those which were found in mid-channel growing on the fine substrate at station 5. Substrates with predominantly larger grain sizes indicate less stability, which prevents aquatic organisms as well as the fine sediments from settling and accumulating. In addition, the invertebrate taxa which occur at a given stream location are dependent to some extent on the type of substrate present. For example, the burrowing larvae of the mayfly Hexagenia sp. and the hellgrammite Sialis sp. are found primarily in substrates composed of medium to fine sediments containing considerable amounts of detritus. Likewise, many of the mayfly and stonefly species inhabit only the surfaces of large-grained sediments, such as pebbles or stones.

The alteration of the stream banks and the dredging of the channel at station 5 seemed to have no effect on the total abundance of invertebrates in the channel. The densities were very similar between the samples collected prior to

channelization (August and November) and those collected afterward (March and May). However, the number of taxa appeared to be somewhat depressed by the alteration, and the abundance of certain invertebrate groups, such as damselflies, caddisflies, and amphipods, were reduced drastically following the channelization.

Tiro Septic Tank Effects

The results of the more detailed studies in the Tiro area indicate that septic tank effluents in Tiro have a definite effect on stream water quality in upper Honey Creek. The increases in concentrations of soluble orthophosphorus and ammonia in the town, and the high proportion of the total phosphorus in the soluble form indicate sewage pollution. The high ratio of fecal coliforms to fecal streptococci indicates human sources as a dominant component of that sewage. This data coupled with direct observation of numerous tiles emptying sewage into the stream in the town leave no doubt that human septic wastes are entering the stream in Tiro and affecting stream water quality.

With respect to water quality, there are probably three major effects of the Tiro inputs. The first of these is the elevated bacterial levels which indicate health risks for recreational uses of the stream. A second effect that is adequately documented in this study is the elevation in nutrient concentrations in the stream stretches immediately below the town. These elevated nutrient concentrations would

be observable under most non-storm stream flows but become more pronounced as stream flows diminish. Elevated nutrient concentrations are no longer evident at the New Washington gaging station due to both dilution from other tributaries and biological and/or physical removal of phosphorus from the flowing water. The biological communities in the stream below Tiro did not appear to be adversely impacted by the elevated nutrient concentrations.

The third effect of the Tiro inputs concerns their contribution to the total phosphorus loading from Upper Honey Creek. Evaluating this effect is much more difficult than the previous two effects in that loading studies require both concentration and flow measurements. The extent to which loading from Tiro varies with the season and stream flow conditions has not been investigated and such studies would be extremely difficult under high flow conditions. The low flow loadings observed on three occasions were 0.12, 0.27 and 0.24 kg/day. If one assumes that the average loading from Tiro were 0.25 kg/day, the annual loading would be 91 kg/yr. This assumption could be valid if a large portion of the loading were from septic tanks which have failed to the extent that the leach fields or wells are totally nonfunctional and the effluent from the septic tanks enters tile systems which lead directly to the stream. Such loadings could be relatively constant the year round. Most of the soils in the Tiro area are not well suited for septic tank systems because of low permeability and seasonal high water tables (Steiger and Powell

1975). Nevertheless, as long as the effluent is passing through a soil system it is likely that most of the phosphorus will be adsorbed (Jones and Lee 1979). This is especially so for the silty clay loams which are dominant soils in the area. If anything, the period from late winter through early spring during which these these measurements were taken may reflect higher than average septic tank loadings. If one assumes that the values of 0.25 kg/day and 91 kg/yr are approximately correct, the significance of this value depends on the point of reference. For the Honey Creek watershed as a whole, long term studies at the Melmore stream gage indicate a unit area total phosphorus export of 1.09 kg/ha. The drainage area at Melmore is 38,600 ha and the average total phosphorus loading is 42 metric tons per year. The population above the Melmore gage is about 6830 giving a population density of 18/km. At station 3 below Tiro, the drainage area is about 380 ha, the population is about 360, and the population density is about 95/square km. If the unit area phosphorus yields at Melmore are applied to this portion of the basin, the total phosphorus yield would be 414 kg/yr and the 91 kg/yr from Tiro would be responsible for 22% of the load. The drainage area of the entire upper Honey Creek at the New Washington gaging station is 4400 ha, the population is 606, and the population density is 14/square km, a value much closer to that of the Melmore station. Application of a population equivalent from Tiro (0.26 kg/yr/person) to the upper Honey Creek watershed as a whole would indicate a phosphorus yield from septic tanks of 157

kg/yr. Again, application of the 1.09 kg/ha/yr to the 4400 ha watershed gives a total phosphorus export of 4,800 kg/yr, of which the septic tank effluents would comprise 3.3%.

The effect of septic tank effluents from Tiro on phosphorus loading is significant for the watershed at station 3 immediately below Tiro. For the Upper Honey Creek watershed as a whole the septic tank effluents do not constitute a major component of the loading. Since the population densities at the New Washington station are close to the average population densities for the entire Honey Creek Watershed, this pilot study suggests that septic tank effluents do not contribute significantly to total phosphorus loading from Honey Creek.

CONCLUSIONS

1. Stream substrates at each of the six upper Honey Creek stations were highly variable spatially and temporally. Sediment grain sizes tended to adjust to seasonal hydrologic conditions. Because of this large variation, the relatively subtle changes in grain size distribution which might accompany conversion to no-till farming cannot be reliably detected with the sampling approach used in this pilot study.

2. The composition and density of the invertebrate communities were highly variable, evidently in response to substrate.

3. In general, the algae, invertebrates and fishes at each station indicated good stream quality, based on the presence of indicator organisms and diverse species assemblages.

4. Concentrations of fecal bacteria were noted to increase during periods of storm runoff. The fecal coliform/fecal streptococcus ratios indicate that the predominant sources of fecal contamination at five of the six upper Honey Creek stations and at the New Washington and Melmore gaging stations are nonhuman. The data further provide evidence that fecal coliform levels may exceed both federal and Ohio water quality criteria at some times during the year at all stations. Fecal pollution may be a substantial problem needing resolution at all six stations.

5. From the occasionally elevated concentrations of fecal coliform bacteria, the high ratio of fecal coliforms to fecal

streptococci, and the elevated levels of phosphorus and occasionally ammonia nitrogen, at station 3 as compared to the other stations, there appears to be a definite, observable influence on stream water quality by septic tank effluents in the vicinity of Tiro. The phosphorus loading from Tiro is significant for the tributary draining the town, but loadings from septic tanks are not significant for the upper Honey Creek watershed as a whole.

6. As a result of large spatial and temporal variations in the substrate and biological communities observed during this study, it is anticipated that subtle changes in the upper Honey Creek stream ecosystem which might be expected to accompany the large-scale implementation of no-tillage practices would probably be difficult to detect based on a limited sampling program. An expanded sampling program or other approaches based on community processes would be required to determine any impact.

RECOMMENDATIONS

1. Continued detailed stream flow measurements, coupled with chemical sampling programs, rainfall measurements, and land cover measurements, offer the best and most direct methods of documenting the impact of adoption of no-tillage practices on the export of sediments, nutrients, and pesticides. Such studies should be continued.

2. Biological community composition, diversity, and structure within this watershed should be determined periodically and compared with the baseline data presented in this study to detect any long-term, large scale response to changing agricultural practices. Future assessments should also include an evaluation of the possible impact of changing agricultural practices upon community processes. Bioassays of community components might provide a sensitive technique for the monitoring of subtle community responses to potential stream inputs.

3. Potential impacts associated with large-scale implementation of no-tillage agriculture within low order stream systems such as the upper Honey Creek Watershed should be evaluated as to the cumulative effects upon the entire drainage basin. Extensive biological, physical, and chemical studies would be needed to determine potential impact upon the aquatic community processes. These should include net community productivity, nutrient assimilation, and nutrient spiralling.

4. Because of the large variation of substrate grain

sizes in a stream reach over space and time, it would be difficult if not impossible to detect changes in grain size distributions which result from changes in agricultural management practices. Thus, efforts to assess substrate changes effected by conversion from conventional tillage to no-tillage and minimum tillage systems would probably not be successful on the basis of grain size analyses. Methods which measure changes in substrate stability, perhaps using sediment traps, might more successfully detect these changes.

5. Fecal bacterial levels throughout the upper Honey Creek watershed appear to indicate that a significant water quality problem exists. A short-term bacteriological sampling program could be established which would entail sampling at sufficiently frequent intervals to determine whether federal or Ohio bacteriological water quality standards are exceeded.

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